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Water resource management by the ancient Maya of Yucatan, Mexico

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WATER RESOURCE MANAGEMENT BY THE ANCIENT MAYA OF YUCATAN,
MEXICO

A Dissertation

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

in

The Department of Geography and Anthropology

by

Terance Lynn Winemiller
B.A., Rollins College, 1993
M.A., Louisiana State University, 1997
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To my father and mother who could not stay with us to see this
work finished.

Kenneth R. Winemiller 1926 - 2000

Doris J. Winemiller 1927 - 1997

and

To my wife, who is not only a source of constant encouragement,
but also was a steadfast colleague in the field.

Virginia Ochoa-Winemiller

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ABSTRACT

Since the publication of popular accounts of exploration by adventurers such as John Lloyd Stephens captured the attention of an audience eager for tales from exotic places, scholars of the ancient civilizations of Mesoamerica have been fascinated with the silent crumbling remains of ancient Maya cities that dot the cultural landscape of Yucatán in staggering numbers. Scientific research began in earnest nearly one hundred years ago with the first of many great Carnegie Institution of Washington, D.C. archaeological projects. Most researchers mention water resources in their reports, but no attempt has been made to study water resource management on a regional scale as an adaptive strategy that enabled the ancient Maya to inhabit a seemingly forbidding environment.

Using the latest computer technology, Geographic Information Systems, and Global Positioning System data collectors, we spent nine months gathering data at over 32 archaeological sites in a region covering the northern portion of Yucatán, Mexico. This paper synthesizes data from my work with an existing body of information collected by other researchers and presents the initial results of what must be an ongoing effort to characterize the options for hydrological management available to the ancient Maya in a variety of physiographic zones. Wittfogel's hydraulic hypothesis and

Robert Carneiro's circumscription model are tested as explanations for the Maya rise to complex society and a model of ancient water management is presented.

CHAPTER 1

CULTURE, LANDSCAPE, AND SETTLEMENT

The scientific mind does not as much provide the right answers as asks the right questions. (Claude Levi-Strauss "The Raw and the Cooked" 1964)

Two Waters of the Ancient Maya

From the earliest Maya occupation of the Yucatán Peninsula of Mexico (Figure 1.1) to the rise of the great cities, the presence of natural sources of water for consumption and agriculture was a fundamental consideration in locational decisions. Environmental conditions commonly cited as factors that serve to limit dispersal of human populations and stimulate centralization such as those found in desert environments, are not characteristic of Yucatán. In spite of the centrifugal nature of the Yucatán environment on ancient populations, evidence of urban centers surrounded by smaller peripheral communities is well documented. Many ancient Maya settlements contained elaborate monumental architecture as well as well-developed internal and external causeway systems that connected internal architectural groups and linked sites to other centers of varying size (Kurjack and Silva Garza 1981). According to some scholars, the largest Maya sites were most likely not very densely populated, having approximately 900

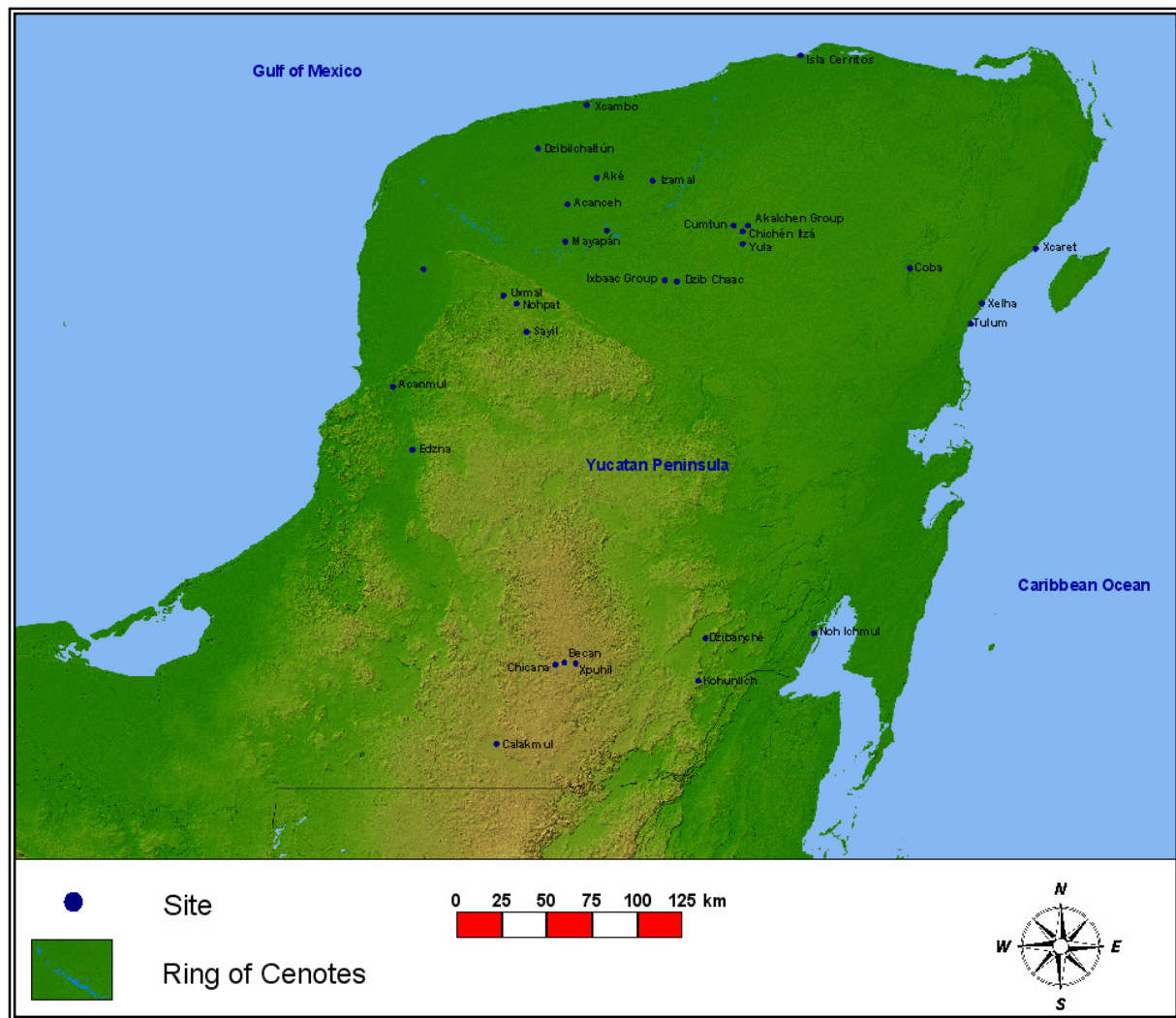


Figure 1.1 The Yucatán Peninsula and sample sites in this study. SRTM Shuttle Radar Topography Mission image courtesy of NASA.

persons per square kilometer (Culbert, Levi and Cruz 1990; Culbert, Magers and Spencer 1990; Culbert et al. 1990). Kurjack and Silva Garza (1981) noted a correlation between volume of monumental architecture and population, thus higher population densities appear to have existed in the central precincts of ancient Maya sites than in the periphery. Archaeological

evidence bears out this assumption. For example, archaeological evidence from Dzibilchaltún in northwestern Yucatán indicates the settlement was a large densely populated site. As distance increases from central areas, there is a noticeable fall off in architectural frequency. Outside of this often site-specific threshold, the Maya were dispersed (Ashmore 1981; Bullard 1960; Culbert and Rice 1990; Scarborough 1993b; Scarborough and Robertson 1986).

The object of this research is to investigate to what extent, if any, the distribution of water resources and resource management systems are related to the centralization of power and rise of complex civilization in the Central and Northern Maya Lowlands and to describe ancient Maya settlement patterns in the context of the distribution of natural and culturally modified water features. Equally important, is to characterize the various types of adaptive strategies found throughout a specific geographic region and reveal patterned spatial associations and relationships between the ideological, behavioral, and material elements of water management systems, and settlement size or environmental variation.

The region as a whole is frequently portrayed as a monotonous forested area of low ecological diversity (Harris 1978). Contrastingly, the Yucatán Peninsula is an ecologically

diverse area. The peninsula experiences dramatic seasonal variation in rainfall. Within its unique karstic landscape, the salient physical characteristic of a major portion of the northern peninsula is its scarcity of streams and standing water.

I was tempted to refer to various physical features and material culture related to the study of the Maya and water in *Mayan* tongue to call attention to the role water as life-sustaining and water as sacred played in the daily lives of the ancient Maya. However, the Maya use toponyms to imbue place significance but often use specific referents interchangeably rendering the *Mayan* terms too ambiguous to employ for a discussion of different types of water features.

Water for both the ancient and modern Maya has a duality of meaning and purpose. Two waters, *ha'* and *zuhuy ha'*, are intertwined and inseparable yet represent two distinct aspects of Maya life. The very same water drawn from the earth to wash clothes and nurture life across the Yucatán Peninsula was also sacred, symbolically sustaining Maya gods who brought life-giving rains to the *milpa*.

Hydrological Management Systems and the Maya State

Historically, water management systems have been investigated using three conceptual and contextual approaches, theoretical debates regarding the advent of state-level society, materialist perspectives, and social symbolic approaches. Additionally, both natural and culturally modified or constructed water features have been documented, described, and classified using various schemes by a large number of researchers in innumerable research reports, papers and articles. Early political studies considering water systems management were published by V. Gordon Childe (1954) and Julian Steward (1949, 1955a, 1955b). Irrigation and hydrological management for Childe was instrumental in a process leading from what he believed to be the Neolithic revolution to an urban revolution. In early works, Julian Steward (1949, 1970) argued that elite control over the construction of irrigation systems contributed to the rise of centralized political power but he later changed his thinking suggesting that multiple causal factors including irrigation contributed to the rise of an early Maya state.

Karl Wittfogel (1955, 1956, 1957) is often credited with the idea that water management was a primary causal factor in the origin of despotic states. Karl Marx preceded Wittfogel in

associating irrigation with centralization of power in Asiatic societies. For Marx, significant historical change could not take place in the absence of environmental modification. He explained the rise of Asiatic state level societies in terms of kin-based village insularity, population growth, and loosely organized segmented groups evolving around a common water system. Subsequently, a despotic religious leader gained control, received tribute and integrated the existing political and economic units of society (Giddens 1971).

Wittfogel's thesis is commonly known as the *Hydraulic Hypothesis*. The term "hydraulic" implies control, and redirection of water as well as elements of human engineering and design (Butzer 1976). Thus "hydraulic" largely referred to irrigation. For Wittfogel, irrigation was elemental in socio-political processes leading to "Oriental Despotism." He argued that centralized political power and authority was the logical result of the necessity for control of construction, management, and maintenance of arid-lands irrigation systems. These ideas were considered to be extreme and deterministic and were challenged by several scholars (Adams 1960, 1966; Carneiro 1970; Leach 1959; Mitchell 1973). Others cited the existence of irrigation systems in many state contexts as support for the causal association between hydraulic management and the rise of

centralized authority (Bushnell 1957; Forbes 1985; Park 1992; Sanders and Price 1968; Santley 1984; Steward 1949). Some researchers argued against the idea of a mono-causal relationship between water systems management and the evolution of state level society (Adams 1960, 1966; Butzer 1971, 1982; Hole 1966; Leach 1959; Scarborough 1993a, b; Sjoberg 1960; Wolf and Palerm 1955).

With the introduction of multivariate systems approaches (Flannery 1968, 1972), water management studies became less politically oriented and more ecologically focused. Ecology is the interaction between humans and their environment. The environment, technology and society are the basic elements of human ecology. Extant thinking about "traditional swidden based" Maya agricultural systems was altered upon the discovery of evidence for the use of raised fields in wetland zones of the Maya Lowlands and research on the socio-political implications of hydrological management systems in the American Southwest as well as other parts of the world (Ackerly 1982; Bronson 1978; Covich 1978; Crown 1984; Culbert 1978; Geertz 1972; Hammond 1978; Harris 1978; Harrison 1978a, 1978b; Hunt 1988; Hunt and Hunt 1974, 1976; Lansing 1987, 1993; Masse 1981; Matheny 1978; Nicholas and Neitzel 1984; Puleston 1978; Rice 1978; Scarborough, Schoenfelder and Lansing 1999; Siemens 1978,

1982; Siemens and Puleston 1972; Turner II 1978a, 1978b; Turner II and Harrison 1978, 1983; Vlcek et al. 1978; Willey 1978; Wiseman 1978).

Recent, studies of water systems centered on economic themes by focusing upon the solutions to various organizational problems involving human labor and resources evidenced in the remains of technologically complex water management systems (Scarborough, and Isaac 1993). One such investigation examined the relationship between hydro agriculture, mass production, and communal labor (Angulo 1993). Other researchers clearly made the distinction between management for storage or consumption and management of irrigation or agriculture (reservoir management versus canal management), sought to account for differences in organizational and technological strategies for each system at various scales of magnitude (Harrison 1993a), attempted to characterize labor specialization for irrigation such as canal engineering, surveying, and construction techniques (Ortloff 1993), or studied the engineering of large-scale irrigation complexes serving large populations (Weigand 1993).

At first glance, Wittfogel's explanation of centralization of political authority based upon control and management of irrigation systems seems to be best suited for semi-arid to

arid environments in the Old World; the example being areas situated along or on the seasonal flood plains of exotic rivers such as the Nile. Ecological and economic approaches go further to explain Maya society and the differences between storage and diversion or channeling of water for consumption and agriculture. Butzer noted the "unmistakable element of ecology" in Wittfogel's ideas (Butzer 1976). For Butzer (1976), irrigation was a complex agricultural and socioeconomic system that represented a three-stage ecological adjustment. First, a new "man-land" relationship, agriculture developed. Structural changes in interpersonal and institutional relationships in society followed the advent of agriculture. Lastly, a new "interrelationship" resulted from interaction of evolving social forms and the preceding agricultural man-land relationships. Accordingly, this new relationship would have enabled the Maya to populate marginal areas and thrive. The ecological approach is central to the study of water systems and Maya society as well. According to Butzer (1976), there are three independent variables and one variable dependent upon the former in the model. The independent variables are environment, technology and population; the dependant variable is social organization and differentiation.

Complexity: Archaeology, Ethnography, Patterns and Models

The following discussion considers various models and perspectives about the nature of centralization, organizational complexity, and water management. My intention is to provide the reader with a clear idea of the nature of centralization and complexity as they apply to this study. The meaning of "centralization" has been discussed by several scholars (Flannery 1972; Geertz 1980; Gelles 1990; Hunt 1988; Hunt and Hunt 1974, 1976; Kelly 1983; Leach 1959; Millon 1962), but there is no universally accepted definition (Erickson 1993). For Gelles (Gelles 1990), centralization "...refers to complex and stratified systems which are characterized by an administrative machinery, judicial institutions, and specialists." Kent Flannery (Flannery 1972) defined centralization as "...a 'linearization' of the linkage between the special-purpose arm of a higher-order system and an important variable in a lower-order system; response is now direct rather than buffered by the village government." For my purposes, the best definition is a combination of Gelles' and Flannery's ideas. Centralization refers to a stratified system with judicial institutions, full-time specialists, and administrative apparatus with power, either coercive or legitimate, extending to, and influencing lower order systems.

Vernon L. Scarborough (1993b) defined water management as "the interruption and redirection of the natural movement or collection of water by society." His non-technological definition of water management does not appear to fully address divisions between components of water management systems. All water systems have three discrete analytical units, a hydrological, a technical, and a sociological dimension. The utility of adopting distinctly technological definitions as units of analyses might be questionable. For a technological dichotomy exists between ancient arid and semiarid waterway societies of the Old World such as those found along the Tigris and Euphrates, the Indus, and the Huangho Rivers and the semitropical civilizations in Java, Cambodia, Sri Lanka, and the Maya Lowlands (Scarborough 1993b). Arid and semiarid civilizations depended upon canals or seasonal floodplain deposition whereas semitropical societies depended upon reservoir systems or storage tanks. Reservoirs are storage areas. In some instances, canals were components of storage systems. These canals served as reservoirs holding excess drainage or they diverted runoff to secondary storage reservoirs.

Defining the discrete technological components of arid zone "Old World" irrigation systems is less problematic than

the same task for the Maya Lowlands. Canal irrigation systems include a facility (gates and "off take" features) to divert water from natural channels and control works (canals, gates, and fields) to transport water to agricultural plants where it soaks into the earth or flows out of the system (Hunt 1988).

The semitropical environment significantly influenced settlement pattern and adaptive strategies of the Maya (Scarborough 1993b). Traditionally, scholars have divided the region into analytical units, physiographic zones, based upon the principal physical characteristics within a particular region. These divisions as Eugene Wilson (1980) referred to them, are useful data for locational analyses. Each physiographic unit is a composite of several physical qualities including drainage, slope and soil types, climate and vegetation. For this study, drainage is particularly relevant as well as climate. B.L. Turner II (1978a) noted that the central Maya Lowlands can be divided into two general categories, either well-drained uplands or poorly drained depressions. Excluding upland / lowland, these two general categories seem to be appropriate for this investigation throughout the peninsula. In Chapter 5, the significance of well drained versus poorly drained terrain in ancient locational decisions is clearly evident. The ancient Maya took

advantage of sloping terrain and natural features by incorporating existing drainage into water management systems, often with few cultural if any modifications. Thus, water management systems reflect two distinct systems of adaptation plus a third amalgamation of the two. I refer to the first as *active* hydrological management strategies (those that involved the use of knowledge, technology and human labor to insure sufficient water for drinking and agriculture) and the second type as *passive* hydrological management strategies (those that took advantage of knowledge only of the consequences of a variety of physical factors upon drainage, diversion, transport and retention of water). Passive hydrological systems represent the earliest form of human adaptation wherein settlements were located adjacent to or nearby natural water features. Passive systems are inherently difficult to identify in the archaeological record. At sites having extensive canal systems linking networks of *aguadas* such as Calakmul and Edzná, a survey of canals proved to be very difficult as their makers took advantage of the relief of natural features throughout the sites. Individual reservoirs themselves are somewhat less problematic to define from a technological perspective except that cultural modifications and the technology used to manage or modify water storage features are often difficult to

separate from natural, non-anthropogenic components.

Furthermore, some functional components of a reservoir system might be architectural elements normally considered to be parts of structures or plazas. This is clearly the case where rainwater runoff is channeled from rooftops, stairways, or more often plazas and terraces into storage tanks as I observed at Chichén Itzá.

Several features associated with conservation or irrigation systems are quantifiable in terms of labor investment for construction, catchment area, overall size, capacity or volume, discharge potential, and area either supported or irrigated. A few scholars argue that a systemic relationship exists between small-scale versus large-scale irrigation systems, societal complexity, and managerial or organizational requirements (Wittfogel 1957; Woodbury 1961). In applying this approach, a combination of direct measurement and calculation of system variables such as those mentioned above is used to infer a particular level of sociopolitical complexity. The central assumption is that size and/or complexity of irrigation or water management systems is directly proportional to societal complexity, so larger systems naturally carry a more complex organizational burden. Wittfogel's thesis demonstrated the role of irrigation and

landscape modification in semi-arid early states (Scarborough 1993b). Given that this study is primarily concerned with spatial relationships, I make no effort to quantify specific units within systems other than to, in some instances for heuristic purposes, characterize them based on apparent size.

How does Wittfogel's thesis fare beyond the arid Middle East? Do his ideas explain the appearance of centralized state systems in the New World? Did irrigation and modification play a similar role in semitropical environments such as the Maya Lowlands? At best, Wittfogel (1957) citing weak links between an apparently quasi-independent artisan-merchant-trading class and ruling overlords, argued that Aztec Mexico was a "semi complex hydraulic society". He went on to suggest the status of Maya artisans and traders was equally problematic but ultimately classified the Maya as a weak hydraulic society. Wittfogel did not believe that Maya rulers were involved in elaborate state-managed trade. Clearly, the position of state involvement relating to trade in both the Valley of Mexico and the Maya Lowlands has received much attention since Wittfogel published *Oriental Despotism* resulting in new ideas about economics and Mesoamerican society (Andrews 1990; Blanton et al. 1996; Brumfiel 1983; Freidel 1979; McKillop 1989, 1996,

1997, 2002; Rathje 1971; Sabloff 1977; Sabloff and Rathje 1975; Santley 1984; Webster 1976b, 1997).

Wittfogel (1957) suggested that complex networks of water temples, weirs, canals, and communal rice paddies in Bali were modern day evidence of a hydraulic society wherein irrigation systems could be tied to the rise of centralized authority. More recent archival and ethnographic work seemingly contradicts this notion. In Bali, paddy rice agricultural communities constructed irrigation systems over long periods of time as cooperative ventures (Lansing 1991). The irrigation systems were, at times, independent of political institutions or the state. Clifford Geertz (1972, 1980) discovered that the Balinese water management systems were controlled by *subaks*, local irrigation associations. The complex network of weirs and channels was regulated instead by a system of religious ritual set in motion by a "state-legitimized purely ceremonial cycle" at the mountain temple Pura Batu Kau, above the rice-growing line, and repeated at lower levels throughout the system to insure each *subak* received the proper allocation of water (Geertz 1980). Furthermore, Lansing (1987, 1991; Lansing and Kremer 1993) discovered an ecological basis for the management of components within the Balinese water temple irrigation system. The Balinese system represents a complex set of

relationships between groups above and below each temple in the network. Water temples are located upstream of the water system, weirs, major canals, blocks of irrigated terraces, *subaks* and irrigated fields, they control. Each feature is linked to a particular social unit, for example all those farmers who obtain water from the system component controlled by a temple god (Lansing 1991). Lansing's work implies that the Bali system is neither state-controlled as Wittfogel argued, nor locally managed as Geertz might suggest.

In northwest Luzon, Philippines Coward (Coward 1979) studied an indigenous group that manages irrigation agriculture independent of a state bureaucracy. All members within the Zanjera Danum system construct, maintain, and own shares in the irrigation network. The association consists of one entire village and parts of two others that are divided into various hamlets. Hamlets are associated with specific *sitios*, field units ranging in size from 15 to 75 hectares in area. *Sitios* are further divided into blocks that line subsidiary canals branching off a main canal. Each block is divided into parcels. Individual farmers hold shares, known as *altars* that consist of several parcels located in different blocks within a *sitio*. Parcels are ideally sequentially arranged within different blocks so the farmer owns the same sequential parcel in all

blocks. The system of ownership serves to reduce conflict among farmers within each *sitio*. Labor is organized into two workforce levels, *dagup*, the total workforce within the system responsible for major works, and *sarungkar*, the labor force responsible for minor routine maintenance and day-to-day operations. There are five *sarungkar* groups within each *sitio*. *Sarungkars* are on call for three and one-half day periods to complete necessary work throughout the system. The labor organization crosscuts *sitios* (hamlets) thereby reducing conflict and insuring that no single portion of the network is favored or better maintained than another. At the *sitio* level, shareholders chose a leader from among their ranks. Three leaders are elected by all of the association to coordinate activities within each of the three branches of the main canal. Each individual branch is associated with one of the three villages belonging to the association. The organization of land holdings and water management ensures equal distribution of water resources and divides the burden of labor fairly among all members of the association. Moreover, the unique organization facilitates expansion of the system without major structural changes. The main canal or branches can be extended to incorporate more *sitios* thereby increasing branch leaders. The Zanjera Danum system of water management is an example of a

locally managed irrigation system with the capacity to expand without centralization of the political structure (Davis Salazar 2001).

For the Valley of Mexico, dialogue about the relationship between water management systems and sociopolitical complexity centered on the sites of Teotihuacán, Texcoco, and Tenochtitlán (Angulo 1993; Doolittle 1989; Millon 1962; Nichols 1982; Nichols and Frederick 1993; Nichols, Spence and Borland 1991; Palerm 1955; Parsons 1991; Price 1973; Sanders and Price 1968; Sanders, Parsons and Santley 1979; Weaver 1993; Wolf and Palerm 1955). If water management was a causal factor in the formation of any Mesoamerican state, no better city existed to test the hydraulic hypothesis than Teotihuacán. The Teotihuacán Valley Project was designed, in part, to discover the role irrigation systems played in the evolution of state level society in the Valley of Mexico. For Sanders and Price (1968) irrigation played a significant role in the development of the Teotihuacán state. Competition resulting from dependencies among users for vital resources and the potential for conflict might have served to drive society toward centralization. Billman (Billman 2002) cited three managerial tasks described by Earle (Earle 1978) that seemingly require a modest level of centralization to accomplish, "... (1) constructing and maintaining canals, (2)

integrating households that use particular canals, and (3) settling disputes and allocating water among canal system users."

Million (1962) cited evidence of wide-ranging variability among small-scale water management systems to argue that no correlation existed between size of irrigation system and the degree of centralization or number of persons supported. Additionally he pointed out that no clear evidence existed to suggest that irrigation naturally precedes the development of central authority. Prior to the 1980s, the existence of irrigation systems in support of intensive agriculture was for the most part inferred by scholars based upon the probable needs of the large population believed to have inhabited Teotihuacán (Price 1973). Little if any direct evidence for irrigation systems or *chinampas* appear in the archaeological record at Teotihuacán during the Classic Period, but the remains of a Terminal Formative Period (ca. 150 B.C.-A.D. 200) system was discovered under the Oaxaca Barrio and possibly the Merchants Barrio (Nichols and Frederick 1993). Nichols and Frederick (1993) argued that the reorganization of streams both in and around Teotihuacán during the Tzacualli Phase (ca. A.D. 1-150), "...affected floodwater and permanent irrigation systems, represents a deliberate, large-scale undertaking that bespeaks

centralized planning and administration." Nichols, Spence and Borland (1991) suggested that the disappearance of irrigation systems could be attributed to the state of Teotihuacán seizing control of irrigated land originally managed by local kin groups for transfer to Zapotec immigrants occupying newly constructed apartment compounds. Nichols and Frederick (1993) noted a similar situation for Maya peoples inhabiting the Merchants Barrio.

Water management systems were present elsewhere in the Valley of Mexico during the Middle and Late Formative Periods (ca. 1050-150 B.C.), the eastern Guadalupe Range (Nichols 1982) and Morelos (Nichols and Frederick 2001). Angulo (1993) used ethnohistoric, ethnographic, and archaeological evidence to reconstruct the nature of the relationship between water management systems and social organization in Central Mexico from 1000 B.C. to A.D. 650. Angulo noted an "obligatory communal labor" system, *tequio*, might have existed as early as the Middle Formative (ca. 1100-850 B.C.), a time when significant human labor was devoted to food production and large-scale infrastructural works projects. *Tequio* served to organize people into collective groups for land and water management (Angulo 1993). Siméon (1977) defined "*tequio*" as *tributo, impuesto, tarea, función, and responsabilidad y deber*

(tribute, taxation, task, function, responsibility and duty). According to Angulo (1993), contemporary native speakers from the region understand *tequio* to mean "...*trabajo communal obligatorio en beneficio del grupo social* (obligatory communal work [done as taxation] in benefit of the social group)." The archaeological evidence for complex hydrological management systems is better documented for the Postclassic Period (A.D. 900-1521) (Coe and Koontz 2002; Doolittle 1989; Nichols and Frederick 1993; Parsons 1991). These systems included irrigation canals, aqueduct networks and *chinampas* erected by and maintained in support of the Aztec state.

The abundant river valleys situated along the Peruvian coastal desert provide an excellent archaeological laboratory to test hydraulic models. In the Moche Valley of Peru water management systems appear in the archaeological record dating to the Early Guañape Phase of the Early Horizon Initial Period (Billman 2002). There are several works (Farrington 1980, 1983; Netherly 1984; Ortloff 1993; Ortloff, Moseley and Feldman 1982, 1983; Wellrski and Wellrski 1982) regarding Chimú irrigation systems of the Late Intermediate Period (ca. A.D. 100-1470). Pre-conquest Andean communities, using various adaptive strategies, exploited the diverse environment for millennia through an economic strategy known as *verticality* (Murra 1972).

Verticality can be thought of as communities seeking economic self-sufficiency through control of as many different ecological zones as necessary to provide a complement to the natural products existing in the local territory. Control was by direct colonization of the different ecozones or resource areas by resident populations. Evidence of sunken fields or gardens, ancient levees, and raised field agricultural plots is found on the Northern Peruvian coast and nearby valleys (Knapp 1982; Moseley and Day 1982; Parsons and Psuty 1975). Moore (1988) and Wellrski et al. (1983) documented raised field plots to the south of Chicama in the Casma Valley as well. Donkin (1979) reported irrigation channels connecting terraces dating to as early as 500 B.C. in the highland river basins. Lake Titicaca, on the *altiplano*, the high plateau, records occupations dating back at least 3000 years (Kolata 1993). Evidence of raised field agriculture was documented at Lake Titicaca as well as other areas in South America (Erickson 1993; Erickson and Candler 1989; Kolata 1986, 1991, 1993; Smith, Denevan and Hamilton 1968).

Recently, Billman (2002) concluded that although the first cycle of political centralization in the Moche Valley of Peru took place during the Guañape Phase of the Early Horizon Initial Period (ca. 800-400 B.C.), the managerial burdens of

irrigation systems such as canal construction, integration of households, and resolution of disputes appear unimportant to the formation of centralized polities or to political change. The same was noted for the formation of a southern Moche state. The results of work in the Moche Valley of Peru suggest that centralization in the Moche Valley was the result of other causes or a combination of factors.

Various surveys of canal irrigation among the Hohokam of the American Southwest addressed the relationship between irrigation systems, social complexity, and centralization of authority (Howard 1993; Neitzel 1987; Nials and Gregory 1989; Nicholas and Feinman 1989; Nicholas and Neitzel 1984; Woodbury 1961). Well before Scarborough's or Lansing's studies in the early 1990s, Richard Woodbury (1961) argued that water management systems in the American Southwest developed over several centuries. Woodbury suggested sociopolitical complexity was not a requirement for the development of Hohokam irrigation systems. Rather, the Hohokam systems represented the cumulative (accretive) results of non-labor intensive, small, periodic constructions over several hundred years (Woodbury 1961). Scarborough (1993b) discussed his notions about a cumulative or accretive basis for water management systems in the Maya Lowlands .

Nicholas and Neitzel (1984) suggested that complex social organization preceded expansion of canal systems beyond local levels. Their study of settlement patterns suggested that an incipient settlement hierarchy existed as early as A.D. 750 - 950 (Colonial Period), and was clearly present from A.D. 950 - 1150 (Sedentary Period), the height of Hohokam irrigation expansion. The presence of early site hierarchy and development of marked site differentiation by the Sedentary Period argued for the existence of complex social organization prior to the expansion of canal systems beyond the early local level.

Nicholas and Feinman (1989) investigated canal system development, settlement patterns and sociopolitical complexity. Their study led them to conclude that sociopolitical complexity increased in conjunction with irrigation canal development. The growth, according to Nicholas and Feinman (1989), ended in the Classic Period, A.D. 1150 - 1375.

Howard (1993) measured discharge capacity, irrigated acreage, and labor requirements for maintenance for Turney's (1929) Salt River Canal System 2 and argued that a pattern of rebuilding and re-engineering in response to ecological pressures, and routine maintenance and repair of the canal system required a complex, centralized administration on the intra-system level. Howard's ideas depart from the model of

accretion proposed earlier by Woodbury (1961). In his approach, Howard employed a "paleohydraulic approach," calculating and tracking changes through time in carrying capacity, irrigated acreage and labor investment to determine patterns of expansion and abandonment. The study suggests that Canal System 2 experienced a lively period of development during the Colonial Period. Thereafter, the system's carrying capacity stabilized until the Classic Period collapse (Howard 1993).

The Hohokam research and ensuing arguments make four problematic fundamental assumptions regarding the relationship between water management systems, in the case of the Hohokam irrigation, and the development of complex centralized society (Davis-Salazar 2001). First, correlations between measurable features of irrigation systems and sociopolitical structure are positively correlated. The positive correlation between size and complexity might not always be the case (Scarborough 1993b). Ethnographic data fail to provide support for this assumption (Hunt 1988; Millon 1962). Hunt (1988) defined irrigation system size as "the extent (measured in hectares) of the fields which are irrigated from the head facility." The results of Hunt's study were in agreement with Lansing and Scarborough's thinking about the accretive nature of water management system development in semiarid areas and

demonstrated that size and complexity are not in all instances positively correlated (Hunt 1988). Second, the sequence and timing of periods of expansion relative to settlement evidence for increased sociopolitical complexity bring to light causal relationships. If system expansion occurred first, it was causally linked to complexity. The opposite is true if evidence for complexity precedes evidence of expansion. Third, models of irrigation system expansion assumed canal systems were used and modified continuously through time, accretion. Howard (1993) modeled this process as episodes of intensive rebuilding and abandonment based upon changing ecological variables. Finally, these modes equate to process in the hydrological system with change in sociopolitical systems. The implication is that sociopolitical structure is the principal "organizing body" of water management systems (Davis-Salazar 2001). Once again, the ethnographic record fails to provide support (Coward 1979; Fleuret 1985; Leach 1959). Hunt (1988) argued that the material remnants of ancient water management systems could only specify the degree of sociopolitical complexity in archaeological contexts if conceptual and structural links having testable implications were established between the two.

If sociopolitical structure is always the operational and organization body of water management systems, physical changes

in the system through time imply sociopolitical change (Ackerly 1982; Neitzel 1987). The sociopolitical complex is then responsible for design and planning, implementation, maintenance, and allocation of resources in support of the system. In this instance, Wittfogel's thesis requires that large-scale expansion and inauguration of control mechanisms such as retention ponds, gates, or weirs in irrigation systems proceed hand-in-hand with increased social complexity.

Palerm (1990) and Palerm and Wolf (1972) surveyed early colonial documents for mention of irrigation systems in ancient Mesoamerica above the Isthmus of Tehuantepec. They searched for mention of "hydraulic complexes" meaning terraces, springs, rivers, arroyos, check dams, swamps *ciénagas*, irrigated fields, and raised gardens *chinampas* (Weigand 1993). They found a total of 382 mentions of irrigation. Using field survey and "on-the-ground" inspections Weigand (1993) encountered dense ancient settlement systems and a substantial amount of well-developed, contemporaneous irrigation systems in the same area, within the basins of Etzatlán-Magdalena and Teuchitlán, Jalisco, Mexico. Weigand reported that the earliest evidence of hydraulic works belong to the Classic Period (ca. A.D. 200 - 900). He further noted that complexity in settlement systems preceded the hydraulic systems by at least 1,500 years. Evidence of long-

distance trade, monumental architecture, elaborate burials and ballcourts suggest societies in the region were most likely organized into states by the Teuchitlán I Phase (ca. A.D. 400 - 700) (Weigand 1993). Hydraulic systems of the time consisted of terraces, canals, spring management and *chinampas*. *Chinampas* zones appear to have evolved in two possible ways. Some of the systems were most likely independent irrigation areas that were ultimately incorporated into engineered larger systems. Regardless of the formative process, Weigand (1993) argued that the large *chinampas* systems ultimately became prime economic resources (Weigand 1993).

Maya Water Systems and Settlement Units in Perspective

Wittfogel (1957) argued that the unique ecological and cultural features of Maya society overlay constructional, organizational, and acquisitive conditions similar to those found in other marginal agro-managerial societies. He suggested that elaborate hydraulic developments existed in the Valley of Mexico, an area Wittfogel considered to be the "hydraulic core of Mexico," and highland regions to the south in Maya inhabited zones of Guatemala and Honduras. Furthermore, he cited the karstic nature of much of the Yucatán Plain and hill zone as a limiting factor for hydraulic enterprise and an obstacle to

permanent populous settlements. Populations entering the region were first challenged to construct reservoirs to store water for human consumption or locate naturally occurring water. Thus, Wittfogel expected to find hydraulic features throughout much of the Maya Lowlands to play only negligible roles in other agrarian societies. According to Wittfogel, the inhabitants of Yucatán found drinking water in "artificial wells" (he labeled them wells or *cenotes*), cisterns or *chultunes*, and "man-made" or culturally modified large naturally formed reservoirs (*aguadas*). Today, the Spanish words for well, "*pozo*" and collapsed dolines (surface depressions on limestone rock found in karst environments) with water at their base "*cenotes*" are used interchangeably throughout much of Yucatán. Wittfogel (1957) pointed out that "...even after the introduction of iron implements, the maintenance and use of the man-made wells often required ingenious communal action," in some instances the participation of the entire population of a community. But, artificial wells could not have provided sufficient water for consumption by large populations. Instead, Wittfogel believed other features such as the *chultunes* and *aguadas* of Yucatán were fundamental to human survival on the peninsula. Stephens (1843) documented the ubiquitous *chultunes* scattered over all of the site of Uxmal and beyond. Wittfogel

(1957) cited Stephens who proposed that the assemblage of *chultunes* represented an "immense" reservoir for supplying water to the ancient population of Uxmal. However, Stephens believed the *chultunes* only "in part" supplied the water for the ancient inhabitants of the city. Although early on in his discourse Wittfogel suggested the Maya did not fit the hydraulic pattern, he later fit the ancient inhabitants into his hydraulic scheme. According to Wittfogel (1957) *aguadas* were more significant from the hydraulic perspective given that their construction, maintenance, and expansion in all probability required large-scale cooperation. Thus, he characterized Maya civilization relatively high in "hydraulic density." Moreover, he argued that the Maya were a borderline case of loose hydraulic society, Loose 2, meaning hydraulic agriculture lacked economic superiority but was sufficient enough to assure leaders absolute organizational and political hegemony, and M 1, definitely Oriental with regard to social control (Wittfogel 1957:166, 188).

Prior to the latter part of the last century, Maya sites were perceived to be "vacant ceremonial centers" with no significant urban population (Thompson 1970). Therefore, Maya ceremonial centers, as perceived by Thompson and others, did not require intensive agriculture to sustain urban populations.

At the time, the Maya model fit well within Wittfogel's hydraulic hypothesis that complex urban societies developed from less complex groups practicing intensive agriculture in semi-arid and arid regions of the world.

A Maya equivalent of urban populations existed at some sites in the Maya Lowlands (Carr and Hazard 1961; Willey 1979; Willey, Leventhal, and Fash 1978). Furthermore, evidence for intensive agricultural and/or short-fallow swidden practices by the ancient Maya is found throughout the Yucatán Peninsula (Beach and Dunning 1997; Culbert, Levi, and Cruz 1990; Denevan 1982; Doolittle 1989; Dunning et al. 1998a, 1998b, 1999; Eaton 1975; Fedick 1994; Fedick and Hovey 1995; Flannery 1982; Ford 1986; Gliessman et al. 1983; Harris 1978; Harrison 1978a, b, 1993a, b, 1996; Harrison and Turner II 1978; Healy et al. 1983; Matheny 1976, 1978, 1979, 1983; Netting 1977; Nichols and Frederick 1993; Puleston 1971, 1978; Puleston and Puleston 1971; Sanders 1977, 1979; Sanders, Parsons and Santley 1979; Scarborough 1983, 1993a, b; Scarborough and Isaac 1993; Siemens 1982; Siemens and Puleston 1972; Turner II 1974a, b, 1978a, b 1983; Turner II and Harrison 1978, 1983; Vlcek, Garza De Gonzales and Kurjack 1978; Weigand 1993). Clearly, the archaeological record provides abundant evidence of intensification and short fallow horticulture in parts of the

Maya Lowlands. Debate as to when or how the change took place is not a goal of this paper. Thus, discussion of the transition from horticultural to more-intensive agricultural practices will be necessarily limited to subsistence practices as they bear upon our understanding of the relationship between water and human locational decisions, and whether or not management of water systems was pivotal in the centralization process among the Maya. Moreover, the argument regarding the centrifugal nature of Maya subsistence practice is valid if we consider that there are no districts within the region of study today that are not supporting *milpa* horticulture. Thus, the possibility of this method being as widespread in the past as today is highly likely. Evidence for intensive systems is at best spotty throughout the region and most likely does not represent the norm.

Prior to the early 1970s, *milpa* or slash and burn agriculture was believed to be the only traditional subsistence strategy used by the ancient Maya. Thus, the numerous Maya sites were believed to have functioned as ceremonial centers. Furthermore, it was believed that these "vacant ceremonial centers" (Thompson 1970) were most likely occupied by a class of priestly elites who were supported by specialists and a dispersed horticultural population living in small communities

and farmsteads more or less evenly scattered throughout the periphery. More recently, (Carr and Hazard 1961; Willey 1979; Willey, Leventhal and Fash 1978) documented evidence of urban populations that lived in high-density civic and ceremonial centers. Moreover, several scholars have noted the existence of cultural landscapes associated with raised fields, terracing, large and small-scale irrigation systems, and water retention (Chase, Chase and White 2001; Fedick 1994; Fedick and Hovey 1995; Flannery 1982; Harrison 1978a; Harrison and Turner II 1978; Healy et al. 1983; Matheny 1976, 1978, 1979, 1983; Mathewson 1984; Puleston 1978; Scarborough and Isaac 1993; Siemens and Puleston 1972; Turner II 1974a, b, 1978a, b; Turner II and Harrison 1983). In the Candelaria Basin, Campeche (Pohl 1990; Siemens and Puleston 1972) and Pulltrouser Swamp (Turner II and Harrison 1983) noted raised fields. Similarly, raised fields were noted in the Southern Lowlands at Cobweb Swamp, Nohmul, and Cerros (Scarborough 1983; Scarborough and Robertson 1986; Scarborough and Gallopín 1991 and Bajo Morcoy Acatuch (Harrison 1978a). Several reviews of the relationship between land and resource modification and ancient Maya subsistence strategies exist (Dunning 1992; Fedick 1995; Fedick and Hovey 1995; Flannery 1982; Harrison and Turner II 1978; Killion 1992; Pohl 1985; Rice 1993).

Ancient Maya agricultural practices and the physical environment of the Yucatán Peninsula are centrifugal factors that serve to maintain a dispersed population. While studying settlements and architecture in northeastern Central America, Sapper (1905) noted the "questionable" distribution of water in the Yucatán influenced the placement of principal buildings in settlements serving to scatter them over the landscape. Adams (1981) noted a widely distributed pattern of hilltop, walled farmsteads (house lots) associated with terraces throughout the Petén, as evidence for intensification. Vlcek, Garza De Gonzalez and Kurjack (1978) reported walled house lots at Chunchucmil. Similar patterns of walled farmsteads and terracing exist in parts of Coba, Dzibilchaltún, outside the wall at Mayapan, and Chichén Itzá and are likely to be found throughout much of the Lowlands periphery.

The positive relationship between the presence of water, productive soils and human settlement is manifest. William Bullard (1960) suggested that relationships between potential water sources and household locational choices explained a clustered - dispersed (more clustered) settlement pattern found throughout northeastern Petén, Guatemala. In semitropical South India and Sri Lanka, environments similar to parts of the Maya

Lowlands, a "one tank, one village" organizing principle exists (Chambers 1980; Leach 1961; Scarborough 1991b, 1993b).

Finding both reliable sources of consumable water and productive areas to raise crops amid the unevenly distributed soils of Yucatán was imperative for sustainable Maya communities. Accordingly, the ancient terraced hilltops, raised-fields, and evidence of the alteration of *bajos* found throughout the Maya Lowlands are not counter to the notion of a clustered - dispersed Maya population. For example, in the Petén region, evidence of ancient farmsteads is found where arable lands suitably elevated above *bajos* existed in the past. In effect, throughout portions of the Maya Lowlands wetland areas served to disperse groups rather than produce large concentrations of people. Turner II (1974a) estimated that suitable lands cover approximately 60 percent of the zone. Weathering processes, topography, and the presence or absence of hardened limestone outcrops determine where arable soils are located in much of the northwestern peninsula.

In spite of the diverse physical environment in the Maya Lowlands, ancient populations adapted in various ways to local habitats and were able to inhabit much of the region. The Guatemalan pattern noted by Bullard (1960) characterizes settlement in northern Yucatán as well. Coe (1961) argued there

were no significant resource limitations or geographical features to govern Maya locational possibilities. Locational alternatives for the early settlers in the region were limited by the distribution of water for consumption producing passive adaptive responses. The earliest occupations in the Maya Lowlands should be found near available sources of water such as caves, rivers, lakes, *cenotes* or flooded bottomlands. Adams (1991) noted that *cenotes*, natural water sources, might have first attracted settlers to Chichén Itzá.

This research considers ancient human locational decisions in the context of scarcity of water and seeks to define the role of water resource management in the cultural development of centralized society among the Maya in the Northern and Central Lowlands. In roughly one half of the study area, a crescent shaped zone extending from the northeastern tip of the Yucatán southward to modern day Chetumal then westward across the peninsula to Campeche, water scarcity was of little or no concern. Although these areas were subject to patterns of seasonal rainfall as were their northern counterparts, groups living in this type of environment struggled more often with issues of drainage and diversion. Additionally, they were 1) advanced beyond merely responding to their environment, 2) captured sufficient water for survival, and 3) engineered

grand-scale projects to move water long distances, often several kilometers. Clearly, the Maya of northwestern Yucatán had a more difficult time dealing with water related issues. In spite of environmental challenges, ancient Maya groups adapted in various ways and dispersed themselves across a large portion of the peninsula.

Several theorists have associated physical factors in causal ways to centralization and the rise of ancient Maya civilization on the Yucatán Peninsula. Wittfogel (1957) as mentioned above noted that the construction of *chultunes*, wells, and modifications to *aguadas*, found throughout the region represented Maya functional equivalent of irrigation works in hydraulic societies. For Carneiro (1970), a critic of Wittfogel, resource circumscription leading to intensification of warfare best explained the origins of early states. Adams (1977) suggested that a sequence of causation initiated by water impoundment may have been a centripetal force in the development of Maya civilization.

Existing studies of water resource management cover a broad spectrum of issues. As an integral part of the human - environment relationship, natural water features and archaeological evidence for storage or diversion of water found in the archaeological record are rarely omitted from site

reports and publications and are frequently described in detail. These innumerable publications exist in numbers well beyond the scope of this research to consider, however, those surveyed provided a rich source of data for this research.

Several studies go beyond description and seek to understand the relationship between water and settlement at a larger scale (Barrera-Rubio 1987; Denevan 1982; Doolittle 1990b; Dunning, et al 1998a, 1998b, 1999; Ford 1986; Freidel and Scarborough 1982; Harrison 1982, 1993a, b, 1996; Luzzadder Beach 2000; Matheny 1976, 1978; Mitchell 1973; Ortloff 1993; Rissolo 2001; Scarborough 1983, 1993a, b; Siemens 1982; Steward 1970; Turner II and Harrison 1978; Weigand 1993; Wittfogel 1957). Their efforts bring us closer to understanding the role, if any, of water resource management in the rise of Classic Maya civilization and the evolution of a centralized elite power base.

In the following chapter, various ideas about the concept of culture and how a regional study of settlement patterns will help us answer questions about the adaptive nature of ancient Maya society before the Spanish Conquest are presented. Two explanations for the development of high civilization in the Maya Lowlands, Wittfogel's (1957) hydraulic hypothesis and Carneiro's (1970) resource circumscription model are discussed

in the context of known information about Maya hydrological management regimes and information lacking to adequately assess the relevance of these ideas to explain the rise of Maya civilization. I also present the fundamental assumptions about human locational decisions and resources I employed in this paper. In the final section of chapter two, the program of research and methods employed to gather, organize, and analyze data about ancient water management systems are presented. A substantial portion of the following discussion concerns the methods employed to develop a project geographic information system and recovery of data from existing publications and maps.

Chapter three describes the physical environment of the Yucatán Peninsula and defines the boundaries of the area of study. The nature of karst and its impact on the availability and quality of water for human consumption is part of the following discussion. To provide the reader with the essentials for understanding the problems addressed in this paper, I present a hydrological vocabulary as the various characterize and variety of natural water sources and constructed features are introduced into the text. The discussion also includes various notions about how a variety of physical and social factors might combined to produce the archaeological landscape

and patterns of settlement existing today across Yucatán, Mexico.

In chapter four artifacts collected during fieldwork are presented. The chapter includes a discussion of the implications of ceramic analysis for understanding hydrological management regimes and the adaptive strategies employed by the ancient inhabitants of the peninsula. The reliability of surface collections as tools for archaeological inquiry is part of the discussion. Descriptive statistics are used to examine the relationship between form and context as it applies to this problem. A significant amount of energy was devoted to developing a modified "short format" (Ball 1978) presentation of the project ceramics and artifacts in Appendices B and C. The collection is presented in a way to facilitate comparison to other collections as well as note similarities and differences between water feature and non-water feature related contexts.

Chapter five is a descriptive account of the data collected in the field. The chapter is organized by physiographic district (Wilson 1980) and ordered by site ranking in the *Atlas Arqueologico del Estado de Yucatan* (Garza and Kurjack 1980). Both site and situational data are presented within each section. Findings as they relate to the research

questions are discussed at the site level then compared to data from other sites at the district and regional scale.

Final thoughts and considerations about water and the Maya developed during this study are presented in Chapter 6. The final discussion includes a summary of fieldwork and inferences drawn from the study. A model describing the various adaptive strategies discovered and the physical or social factors that seemingly influence preferences for one over another is presented.

A brief glossary is provided in Appendix A. As mentioned above, Appendices B and C detail the ceramics and artifacts collected during field survey. Appendix D contains a list of abbreviations used for tables presented in the text.

CHAPTER 2

PERSPECTIVES AND RESEARCH METHODS

Ideas about Culture and Settlement Patterns

Water and water-management influenced the construction of the ancient cultural landscape of northern Yucatán. Settlement patterns are the visible remains of cultural and social factors interacting in varying ways, and at different times. The best way to approach the question of water and the Maya is to investigate regional settlement patterns.

For this paper, I adopted a cultural ecology perspective to explore the relationship between the ancient Maya and their physical and social environment. Thus, culture in ancient Maya society is considered to have been, in part, the way individuals and human communities adapted to varied environments to insure long-term survival. Anthropologists and geographers employ particular understandings of culture and cultural systems in their efforts to explain processes involved in the construction of cultural landscapes and formation of specific relationships between society and nature. Steward (1955a) suggested that environment and culture are engaged in "dialectic interplay as feedback or reciprocal causality." For Steward (1955), the environment played an active, not just a

confining or selective role, in human affairs. Moreover, at times culture plays a more active role, and at others, the environment appears to come to the fore. This cyclical nature of cultural response to environmental change is best illustrated by historical expansion (migration) into, or retreat from regions in response to changes in the political, economic or physical environments. Like Steward, Denevan (1983) suggested the diachronic and spatial nature of cultural adaptation is variable over short periods of time, reflecting both environmental and socio-economic change.

For Earle (1992), the mission of geographers is "...the comprehension of changes on the earth's surface." Transformations of physical environments are the result of either natural processes or are anthropogenic in nature. Earle challenged researchers to "...ponder the interactive effects of nature and culture within specific locations and times." A society is "...embedded in its own context, that is, in place- and time-specific ecologies" (Earle 1992). Thus, human adaptation - innovation is place-specific. The concept of place represents not only location, but also condition. "Condition" presupposes the temporal and spatial interplay of both physical and social phenomena in the construction of place. This dissertation explores the culture ecology of place in an

ancient society. Sauer (1925), viewed culture as an "agent" and the environment as a cultural artifact of process. This process can be discerned from patterns in the archaeological record. For Wagner and Mikesell (1972), geographical cultural ecology was the study of specific processes. Grossman (1977) argued that understanding the process in man-land relationships requires analysis of values, social beliefs, and social organization at the micro-scale. At any societal scale, adaptive options correlate to variable levels of technological proficiency.

The degree of technological competence within a particular society can either enhance or limit a society's ability to adapt. Clarke (1965) suggested that habitability of marginal areas increases in time and space as technology enlarges resource bases and overcomes physical obstacles. Furthermore, White (1959a, b) maintained that cultures developed according to the amount of energy they are able to transform through technology. According to White, technology is essential to a society's ability to thrive in a particular environment. Technology has both an ideological and material component.

Technology in human society includes its ways of doing things. The ancient Maya employed technology to channel or conserve water for direct human consumption and household uses,

and for agricultural purposes. Hydraulic technology empowered the ancient Maya populations to occupy marginal areas. Both ideas and material culture are transmitted through human interaction. Mapping spatial distributions and frequencies of water-management features, by type, reveals hearths of innovation as well as networks whereby particular technologies spread. Analysis of the patterns of occurrence within network structures isolates the mechanisms whereby particular adaptive responses were accomplished in northern Yucatán (Yapa 1996).

Cultural landscape, as a material artifact, possesses elements of a society's conceptual inventory. Therefore, aspects of the symbolic structure of the ancient Maya world as well as their material culture are studied through analyses of the archaeological record. Symbolic principles and concepts represent a structure that influenced the patterning of material culture (Hodder 1982). Authority of emerging ruling elites in preindustrial agrarian societies was socially justified by incorporation of political ideology within religious cosmology (Geertz 1980; Sjoberg 1960; Wheatley 1986). Subsistence and belief systems, as this paper demonstrates, are inseparable elements, the *ha'* and *zuhuy ha'* of the Maya worldview. In the past, ruling elites strengthened their privileged status by binding their roles in society to Maya

cosmology. The elite established themselves as ritual stewards of natural order. Dunning (1992) proposed that the Maya ruling elite "geo-scripted" the natural world as one part of a general interlinked system of territorial definition and control. In certain contexts, the elite in Maya society employed the sacred aspect of water in order to legitimate their power and construct a Maya cosmology specifically for the construction and maintenance of hydrological management systems.

The ancient Maya of the northern Yucatán Peninsula practiced a combination of *milpa* or swidden agriculture and hunting as many traditional Maya do today. The physical environment played a significant role in Maya day-to-day life, both creating and limiting possibilities. The archaeological record indicates the Maya made use of a variety of adaptive strategies to compensate for seasonality of rainfall and a dearth of surface water in many areas. By channeling and storing water, they settled in areas having no apparent natural sources of surface water (Adams 1977; Denevan 1982; Doolittle 1990a; Dunning 1992; Ford 1986; Freidel and Scarborough 1982; Hammond 1990; Harrison 1977, 1982, 1993a; Matheny 1978, 1982; Scarborough 1993b; Scarborough and Isaac 1993; Sharer 1994; Siemens 1982).

Settlement pattern research assumes that settlement preserves information about the number and density of people occupying the landscape at any point in time and the spatial organization of human activity. Willey (1953) defined settlement pattern as "the way in which man disposed himself over the landscape on which he lived." Settlement is a reflection of a relict environment, the level of technology upon which a group of human beings operated, intergroup social and political interactions, and the wealth and status within a society. The determinants of settlement patterns operate at three levels that vary both qualitatively and quantitatively from one level to the next (Trigger 1968). Investigating the relationship among culture, adaptive strategies, and the physical and social environment at each scale of settlement - the building or structure, the community, and the region is essential - to understanding the formative processes that contributed to a particular pattern (Trigger 1968).

Traditional settlement pattern studies have been directed toward two problems, those concerning people in their relationships to their natural environment, and those dealing with the social and political relationships among people (Ashmore and Willey 1981).

Ancient settlement patterns in the northern peninsula are considered within the context of a nature-society relationship. Although largely focused upon analysis of human adaptive systems and the role of physical factors in human locational decisions, I adopted a space-society perspective (Hanson 1999), the recognition that human action generates a constructed environment, and in part, shapes spatial decisions as well. Accordingly, the social environment, the distribution of villages and settlements, and the availability of natural resources such as water or arable land might have ultimately lead to autonomous political units of increasing size and decreasing quantity throughout parts of the Yucatán Peninsula. Independent settlement units might have ultimately found themselves socially circumscribed leading to competition for space and resources and warfare for expansion. In Robert Carneiro's model, the conquered became tribute paying political entities under the dominant conquering social group. Carneiro (1970) proposed this explanation for the rise of complex society along the ancient Peruvian coast and elsewhere. If Carneiro's model explained in part centralization and development of high civilization in the homogeneous flat plains of the Yucatán Peninsula, evidence of warfare and conquest should appear at a number of higher-order settlements situated

somewhat equidistantly from each other surrounded by a more-or-less equal distribution of lower-order settlements. Evidence of warfare would include fortifications such as walls or moats and iconography of war including murals, altars, and stelae depicting conquests of ruling elites. Considering zonal variation across the study area, the aforementioned pattern might be expected to vary within separate zones. For example, the density of higher-order sites might be higher and distances between them lower in the southeastern portion of the study area where water resources are more readily available than in the drier northwestern portion of the peninsula. If these conditions are found not to exist in the Maya Lowlands, then Carneiro's explanation fails to elucidate the forces impacting the distribution of settlements among the ancient Maya.

Clearly, other factors might have influenced settlement decisions. Subsistence technology is often cited as a prime environmental factor influencing human locational decisions. Several regional and site-specific studies have focused on Maya subsistence strategies (Doolittle 1990a; Flannery 1982; Ford 1986; Mathewson 1984; McKillop 1997; Pohl 1990; Puleston and Puleston 1971; Vlcek, Garza De Gonzales and Kurjack 1978). The two basic elements necessary for a successful horticultural subsistence strategy are tillable soils of minimal quality and

a sufficiently long rainy season or the technology to irrigate planted fields. Humans need water for direct consumption (drinking) and household activities to survive as well. Therefore, areas determined habitable by the ancient Maya of the Yucatán Peninsula must have had either naturally occurring resources or the potential for cultural modification to provide both water and cultigens.

Essentially, the development of social organizations may be viewed as a group means of minimizing environmental risks through the development of food storage and redistribution in complex societies (Butzer 1982; Porter 1965). Human ecology theory makes the assumption that population density and the intensity of subsistence routines are linked variables in cultural systems (Alland 1975; Boserup 1965; Butzer 1982). If changes in population, environment, or population - environment relationships occur, then changes in subsistence strategies, resource use, and social organization will follow. These transformations will be reflected in the settlement patterns (Ford 1986; Glassow 1978; Steponaitis 1978). Population growth has been cited as causal in increasing societal complexity (Boserup 1981; Faris 1955; Fried 1967; Gall and Saxe 1977; Geertz 1963; Service 1975) suggested settlement variability and differences in local community economic organization depended

upon the environmental setting. Ford (1986) argued that societies had two options in their adaptive responses to population growth, expansion into peripheral areas, or modification of the use of existent areas: (1) expansion resulted in little or no alternation in access to critical resources (water) or in organizational structure, or (2) when expansion was no longer an alternative, a series of changes evolved including modification of subsistence strategies, and increasing economic differentiation based upon unequal access to vital resources. In Ford's (1986) model, elite concentration for administrative purposes and spatial centralization around vital resources followed continued population growth. Thus, demographic and structural adjustments in ancient Maya society transformed the cultural landscape. We can analyze settlement for change in water-management that may have resulted from a demographic or structural process.

Geographic Regions and the Archaeology of Yucatán

Geographers make sense of the world by synthesizing large amounts of data into spatial categories based upon the presence of similar physical and cultural traits shared by the inhabitants of a particular area. These areas are known as regions. The defining characteristics might be material

(material culture) or ideological or a combination of both. If culture is integrated, then material culture, a product of human thought, represents conceptual culture. Archaeologists and Geographers can interpret unintentional modifications to the physical environment in terms of the society that produced them as well. Geographers seek to understand the complex relationship between humans and their environment. This dissertation is unique in geography in that the society under investigation that inhabited the region and the temporal context is for the most part prehistoric. Thus few records exist that predate the Contact Period. However, a substantial portion of Maya material culture remains long after the innovators are gone. Thus, a substantial portion of the data for this dissertation was gathered from the archaeological record. Both systematic and regional approaches will enhance our understanding of Maya society. The concept of region, as well as definition and adoption of divisions or districts within regions is both instructive and useful in the study of hydrological systems and the ancient Maya.

Based upon physiological differences, Morley (1946) defined three "natural" subdivisions in the Maya area, the mountain ranges and intermediate plateaus, the interior drainage basin of Peten, Guatemala, and the low flat plain of

the northern one-half of the Yucatán Peninsula. Hartshorne (1959) defined region as "...an area in some particular way distinctive in some way from other areas."

By nature, the geographical concept of region implies a degree of physical and/or cultural homogeneity that is shared by its inhabitants. My study area covers a portion of the culture area, a formal culture region known as Mesoamerica. Kirchhoff (1943) intended to define the region as distinct from the great cultures of southwestern United States and northern Mexico. Intensive agricultural practices such as terracing of slopes and *chinampas*, and *milpa* (slash-and-burn) agricultural practices are a few defining cultural traits in Paul Kirchhoff's Mesoamerica. Hence, the regularity of seasonal precipitation was a significant element of ancient Maya life. Wilson (1980) subdivided the Maya Lowlands into fourteen physiographic districts using generalized environmental data such as annual rainfall, soil types, vegetation coverage, drainage to name a few.

Trewartha (1953) considered the physical environment as a dynamic, changing resource base having relevance in terms of "importance for populations of the earth." Therefore, the locational diversity of populations is linked to the nature of places. For heuristic purposes, I consider place as defined by

Smith (1996) to be not only a location, but also a condition. Awareness of the relationship between location and condition is essential to the study of populations (Beaujeu-Garnier 1956, 1966; Clarke 1965; George 1959; Trewartha 1969; Wilson 1968; Zelinsky 1966). The place under study, the northern lowlands and the extreme northern portion of the central lowlands as described by Morley (1946) and Sharer (1994), is homogeneous in some respects and an environmentally diverse area as well.

The antiquity of early hunters in the Yucatán is generally accepted (Coe 1999, 2002; Weaver 1993). Most likely the earliest settlers in the Yucatán Peninsula found the shelter and water in the ubiquitous caves throughout much of the region. From the Middle Preclassic through Postclassic Periods, roughly 1000 B.C. until A.D. 1500, the inhabitants of the region adapted and adjusted to a physically and socially diverse environment (Sharer 1994).

For Dunning (1992), both temporal and spatial patterns of human occupation in the Puúc region were influenced by particular geological and climatological effects on the availability of water. Dunning considered physical environment, cosmology, political economy, and agricultural systems intertwined and accessible through settlement patterns. Building upon the tradition of earlier regional investigations,

such as Ford's (1981) study of the development of society in the Central Maya Lowlands, Scarborough's (1993b) study of water management systems in the Southern Maya Lowlands and Dunning's (1992) survey of settlement in the Puuc Region, I describe and in some instances quantify in the following chapters the spatial relationships and associations between natural resources, in particular water and settlement across the Yucatán Peninsula and the range of variation in those adaptive strategies. This dissertation is not an attempt to discover the origins of various adaptive strategies employed by the ancient Maya to populate the region or redefine already well-established typologies for the elements found in ancient Maya hydrological management systems. My data concerning regional variation in adaptive strategies provides new insight into the environmental and social factors that influenced locational decisions and centralization throughout the Yucatán Peninsula.

Assumptions and Arguments

Water is essential to human life. Several investigators have specifically addressed water management systems throughout the Maya Lowlands (Adams 1977; Ford 1981, 1986; Harrison and Turner II and Harrison 1983, 1993a, 1996; Harrison and Turner II 1978; Matheny 1976, 1978, 1979, 1980, 1982, 1986, 1983;

McAnany 1990; Pohl 1990; Pope and Dahlin 1989; Puleston 1971; Scarborough 1983, 1991a, b, 1993a, 1993b, 1994; 1996; Scarborough and Gallopin 1991; Scarborough, Connolly and Ross 1994a, b; Turner II 1974a; Turner II and Johnson 1979). Current political and economic models only partially explain the complex processes that shaped the cultural landscape of the Yucatán Peninsula in pre-Hispanic times. Archaeologists and geographers cannot translate settlement patterns into descriptions of ancient Maya society without clearly understanding adaptive responses and water resource management practices. As part of the systematic approach to this topic, I followed a geo-archaeological method to settlement analysis similar to that described by Butzer (1982). Using a wide variety of data for the physical and social environment, I modeled the ancient milieu wherein past socioeconomic systems evolved, thus providing an understanding of early Maya ecosystems. I provide an ecologically based model to complement extant political and economic explanations for settlement phenomena. Future synthesis of ideas emerging from this research with those from other studies will provide a more comprehensive account of culture process in ancient Maya society and shed light on the centripetal forces at work in

lowland society that gave rise to unequal access, stratification, and centralization of power in the region.

I constructed a water-resource model for the study area using various hydrological and topographic maps. At one level, the study addresses whether or not early settlements in northern Yucatán were located adjacent to water sources. Here, the fundamental assumption is that adaptation first takes advantage of opportunities that require the least amount of energy or capital invested per unit of output (Boserup 1981; Dunning 1992; Sanders 1960; Zipf 1949). Earlier in Chapter 1, I referred to this type of adaptive strategy as a *passive* response. If this assumption accurately describes the ancient Maya response to environmental variation in the Yucatán, early settlements should be situated near natural sources of water and expansion or later sites will appear at distances from the water supply that are significant enough to require transport or capture, redirection and storage systems. I used architectural and ceramic dating in conjunction with settlement pattern to test this hypothesis. Data from this study appear to bear out this assumption.

At times, certain districts within the region experienced marked water stress as they do today. At sites in settings where seasonally adequate and accessible sources of surface

water exist, construction of water storage reservoirs or modifications to natural features was most-likely prompted by social factors such as population growth, expansion of the agricultural base, or accomplished by a small segment of the society to attain prestige or simply for convenience. If these factors were considerations, then water storage features should follow evidence for population expansion in the archaeological record in a relative chronological sequence. In some cases, the introduction of *aguadas*, water channeling, or construction of *chultunes* and wells appears to have come about sometime after initial settlement of an area. In a few instances, one being a *chultun* situated on a plaza within 65 meters from the shores of Lake Macanxoc, convenience or status might have been the intended result. The Coba *chultun* is evidence of instances where stable sources of water were close at hand and non-economic concerns, perhaps prestige or convenience, appear to have outweighed substantial initial investments of labor to construct or modify storage features. Increasing population densities might have pressed ruling elites, *ahaus* (lords), *halach uinics* (territorial rulers), or *batabob* (local kin group leaders), to organize labor for the construction of public reservoirs (Farriss 1984; Marcus 1993; Webster 1997; Wittfogel 1957). An evolutionary mechanism in a multivariate milieu such

as Flannery's (1968, 1972) concept of "linearization" might help to explain instances like those mentioned previously in the discussion of Wittfogel's hydraulics. In this case, smaller canals seem to have been incorporated into larger works through time. Control and maintenance of canals or constructions under the jurisdiction of local community leaders would have been appropriated by higher-order controls such as a manager whose authority was grounded in a centralized political structure. This scenario would appear in the archaeological record as distinct lower order units sequentially being incorporated into larger polities. In forthcoming chapters, I return to this topic.

Where a long sequence of occupation prompted radial site development outward from plazas situated adjacent to natural water-sources, increasing frequencies of water-conservation features such as *chultunes* or wells should plot in the same concentric pattern as lower order settlement units within the greater urban area. This pattern finds basis in the archaeological record at the site of Dzibilchaltún where varying densities of concentric zonal clustering of water management features delineate the boundary where energy expended in water transport exceeded labor investment to construct water storage or diversionary features. These

threshold values represent modal transport distances. If pan-peninsular rules governing settlement location and water-sources existed, then patterned spatial relationships, and predictable associations between architectural types and water sources or uniform frequencies of water-collection features by type will resolve in regional data. During fieldwork, the distance from water features to settlement units and data regarding patterned associations was documented for each scale of settlement described by Ashmore (1981). In some areas such as the northwestern coastal plains of Yucatán, *sartenejas*, natural karstic depressions that fill with water during the rainy season, most likely provided adequate water supplies throughout the rainy season. In these contexts, zonal patterning indicative of transport distance thresholds might not be present. *Sartenejas* were likely exploited as long as they contained water and *chultunes* were left to replenish themselves by capturing runoff from daily rains.

Puleston and Puleston (1971) attributed the success of Maya culture in tropical rainforest environments to transitions in subsistence and storage technology. Considered to be *active* adaptive options, constructed hydrological management systems employed by the ancient Maya of northern Yucatán fall into three general sub-classifications, movement solutions involving

transportation, diversion, or channeling of water; containment responses for storage; and extraction such as excavation of wells. The decision to utilize a particular strategy might have embodied a social component related to status and wealth. Furthermore, under dissimilar sets of physical and social pressures, an adaptive response such as the construction of a *chultun* undertaken by familial or communal groups inhabiting a household or patio cluster might have been orchestrated and controlled, on a large scale, by elites through the collection of labor tribute or payment of skilled professionals in a fashion similar to the construction of monumental architecture.

Other regional studies of ancient Maya water management systems have focused on the southern Maya lowlands (Gallopín 1990; Harrison 1977, 1993a, 1983; Matheny 1976, 1979, 1983; Pohl 1990; Pope and Dahlin 1989; Scarborough 1991a, b, 1993a, b; Scarborough and Isaac 1993; Scarborough and Gallopín 1991; Scarborough, Connolly and Ross 1994b; Turner II 1974a, b). Wittfogel's hydraulic model has been evaluated in the context of ancient Maya civilization (Scarborough 1993b). Control of water and labor to construct conservation or control systems by elites to sustain rising populations may have been one of many factors that sustained a Maya ruling class (Harris 1978). In the Peten region, creating sources of drinking water where

there were none was the critical technology that permitted populations to survive (Ashmore 1984; Casares 1905; Matheny 1976; Scarborough 1993b; Scarborough and Gallopín 1991).

Archaeological evidence from Dzibilchaltún reported by Ochoa (Ochoa Rodríguez 1995) suggests a correlation existed between ancient wells, and elite structures. Diego deLanda (1978) noted a relationship between elites and wells at sites where few wells existed; "...the wells, where they were few, were near the houses of chiefs". Ochoa excavated a residential complex where the inhabitants apparently depended upon others for water. Throughout the dry season, the residents seemingly walked to one of two known wells in the area, a 70 or 150 meter distance, or carried water from *Cenote Xlakah*, a cenote 400 meters to the west (Ochoa Rodríguez 1995). Evidence collected during this fieldwork and GIS analyses of existing maps and published data appear to support the notion that certain wells, at least at the site of Dzibilchaltún, were part of the space inhabited and most likely controlled by individuals who had the wealth to construct more elaborate platform groups. Given that the settlement data point toward dense populations in a substantially large area around the site core, approximately 20 square kilometers, the Dzibilchaltún evidence alludes to differential distribution, but most likely equal access, to

water extraction and storage systems, such as wells or *chultunes*. If elite control, as suggested for Dzibilchaltún, represents the norm, higher frequencies of water transport and storage vessels and a marked absence of wells or *chultunes* in habitation contexts should be discernable outside of elite contexts elsewhere in the Yucatán Peninsula. The data suggest Dzibilchaltún was not unique in this respect. In the absence of water storage features, higher relative frequencies of water jars and "*chultun* jars," from the ceramic groups, Unslipped *Saban*, Red *Xanaba*, Brown *Chuburna*, Unslipped *Chum*, Slate *Muna*, Unslipped *Sisal*, Unslipped *Navula*, and Unslipped *Panaba* (Brainerd 1958; Smith 1971) in residential contexts would suggest water transport and storage, thus supporting inferences regarding the existence of differential access to water sources at upper order sites.

A combination of theoretical perspectives and methods drawn from archaeology and geography bear on explanations of the ancient human ecology of Yucatán. I employed the latest geographic information systems (GIS) technology, and research-oriented descriptive statistics to test the significance of patterns observed in the field. Analyses of regional settlement patterns were used to determine whether two ideas, Wittfogel's hydraulic society or Carneiro's resource circumscription,

account for the appearance of centralized elite administrative centers supported by a dispersed rural population in an environment where conditions appear to favor uniformly dispersed small-scale settlements. By reformulating Wittfogel's hydraulic hypothesis to consider the social consequences of centralized coordination of water conservation, control, or channeling activities such as greater political integration (Mitchell 1973) and potential economic sanctions like individuals denied access to water (Childe 1954) rather than irrigation itself, we can more easily account for the nature and extent of water systems management in explanations for the appearance of Maya civilization.

If population growth precipitated the establishment of organizational hierarchies based on water control, then regional settlement analyses should reveal recurrent patterns of clustered elite administrative hierarchies (Service 1975) around natural sources of water and evidence of public works for channeling or storage, such as *chultunes*, wells, canals, or *aguadas* within the spatial core of cities. Alternatively, in the periphery the same model predicts water storage features situated to provide free and equal access by all inhabitants. Water management strategies among the dispersed population should appear to be less complex in form as well as

organizational structure. This situation was observed in the field. At the patio cluster scale beyond the range of effective political control, endeavors such as the construction of *chultunes* might have been cooperative projects accomplished by kinfolk or members of small communities. At upper-order sites, construction and maintenance of water systems would have been orchestrated by elites or their attached specialists within the context of a managed system of corporate labor. These features should manifest a marked degree of standardization. This was clearly visible at several sites including Chichén Itzá and Uxmal in the northern portion of the peninsula. The observed standardization mostly concerned the engineering of various components of *chultunes*. Measurable attributes such as depth of neck necessarily varied according to specific locational conditions.

Research Methods

In an effort to account for the diversity of human responses to the variable distribution of water resources throughout the Yucatán region, I posed a series of questions for investigation. (1) Were early settlements in Yucatán located adjacent to water sources? (2) What other additional factors might have affected settlement in the region? (3) What

types of natural and artificially modified water features were employed as adaptive strategies to manage water supply and water storage systems? (4) What features enabled the Maya to expand into marginal areas? (5) What regional variants of adaptive systems occur in the northern peninsula? (6) Can centers of innovation and mechanisms of propagation for regional variants be described as well as their influence upon regional and local settlement patterns? (7) Are varied adaptive systems related to physiographic factors, such as localized climatic variation, elevation, subsurface or surface geological characteristics, or vegetation coverage? (8) Can we construct a settlement chronology based on water management systems? (9) Do micro-level settlement patterns reveal rules governing transport of water? (10) Were the ancient Maya circumscribed by a water resource base? (11) What if any contribution did water systems management have upon the rise of complex society in the northern Maya lowlands? (12) Can the Maya be referred to as a hydraulic society?

Field Operations

Finding suitable answers to my questions required a comprehensive program of research involving a field program of

intensive survey and mapping of sites, natural water features, and cultural hydrological management systems.

Fieldwork was divided into five operational categories. Relevant theoretical points, and project objectives as they relate to specific operational categories are discussed below. Archaeological data including site maps, locational and frequency information concerning natural water sources, water storage or diversion, settlement locations by type and rank were collected from regional offices of the National Institute of Anthropology and History, INAH, in the states of Campeche, Quintana Roo, and Yucatán. Twelve of the largest sites within the region were surveyed. This operation included collection of GPS positions, verification of existing geographical coordinates, identification and classification of water features, and selective surface collections. Site rankings refer to a site classification system based upon architectural development and population estimates, adopted from two sources, Garza and Kurjack (1980) for sites in the modern states of Campeche, Quintana Roo, and Yucatán and Dunning (1992) for specific settlements located in the Puúc area of the northwestern Peninsula. The Puúc zone is a hilly area in western Yucatán, believed to be the heartland of a unique highly decorative architecture style that spread throughout the

northern Maya Lowlands during the period from approximately A.D. 600 to 1000.

Intensive survey of nine upper level sites, one from each of nine physiographic regions (Wilson 1980) in the study area included reconnaissance and mapping of locations of natural and culturally modified or constructed water sources and architecture and registration of artifact frequencies by location within the site. To ascertain whether or not site ranking, based upon population density and architectural development, correlated to variations in the complexity of adaptive strategies, one lower order site from each physiographic region in the study area was surveyed and mapped with a GPS data collector to document principal settlement units, the extent of site development, and review the form and complexity of systems of water transportation, diversion, or conservation features present. Earlier, I suggested that the relationship between natural water features and ancient Maya settlements was axiomatic. Landsat Thematic Mapper and orthorectified air photos were examined to identify areas where the potential for discovering ancient settlements appeared to be higher based upon favorable environmental factors such as the presence of natural sources of water, fertile soils in *rejolladas*, *kom'o'ob* in Mayan, or favorable elevated areas.

During fieldwork one area having no documented settlements was identified and surveyed.

Preparation for the Field and Methodological Considerations

This paper employs a multi-disciplinary approach to explore human ecology through regional investigation of ancient Maya settlements in the Yucatán Peninsula of México. The study explores both intra- and intersite development through verification and analyses of existing data and the collection of new information during field operations. Over the centuries, archaeologists, explorers, geographers, geologists, and historians have published a substantial corpus of data pertaining to this problem. Bernal Diaz del Castillo and Fray Diego de Landa published the earliest accounts of pre-Hispanic life in parts of Mexico (de Landa 1938; Diaz del Castillo 1928). The major thrust of exploration essentially began when Stephens and Catherwood sketched their first map and captured on paper the architecture of the ancient Maya ruins of Copán in 1839 (Stephens 1843).

Few publications concerning the ancient Maya fail to refer to water or methods of capture and storage of water. Assembling these bits of information into an informed regional perspective of water systems management proved to be challenging and could have easily evolved into a consuming, never-ending undertaking.

Even while writing this paper, I uncovered new sources. Since the early days of exploration in the region, there have been several works published that sought to understand the relationship between water and settlement (Barrera-Rubio 1987; Denevan 1982; Doolittle 1990b; Dunning, David Rue, Timothy Beach, Alan Covich, and Alfred Traverse 1998a, b; Ford 1986; Freidel and Scarborough 1982; Harrison 1982, 1993a, b, 1996; Luzzadder Beach 2000; Matheny 1976, 1978; Mitchell 1973; Ortloff 1993; Rissolo 2001; Scarborough 1983, 1993a, b; Siemens 1982; Steward 1970; Turner II and Harrison 1978; Weigand 1993; Wittfogel 1957). Although particularistic, these works represent significant contributions to our understanding of adaptive strategies employed by the ancient Maya to thrive in a challenging environment. However, none explained the range of options provided by the variable peninsular environment and the variety of Maya responses. Many other publications and reports at the micro (site) scale include maps that contain information concerning physical and cultural environments and the relationship between these elements. A portion of my time in the field was directed toward verification of identifiable elements in existing maps and gathering geographic coordinates for registration.

I designed and employed a GIS for predictive modeling, to query spatial relationships and to explore the functional processes responsible for them. In instances where maps of sites were available, most often the case, the research method involved a series of steps alternating between the laboratory and the field. If a suitable paper map or maps were available, they were scanned and converted into raster images.

Architectural and natural features recorded in the scanned maps were selected as ground control points for geo-referencing. In the field, geographic coordinates for pre-selected map elements were collected using a Trimble GeoExplorer III GPS data collector. Within the GIS environment, map elements were registered with their complementary ground control positions. To verify accuracy of the registration process, additional map features were selected from registered maps for ground truth. For those instances where no maps were available, sites were either GPS mapped or mapped with a Laser Total Station. After the registration process was complete and precision tested, I merged non-spatial and spatial information from published maps and literature with my original data to accomplish a variety of problem-oriented goals.

The method described above enabled me to integrate large datasets into this dissertation, an undertaking that would have

been impossible for a variety of reasons to accomplish by means of traditional field survey procedures. For example, the site of Dzibilchaltún is situated about 12 kilometers north of Merida, Yucatán. From December 1963 to August 1964, Kurjack (1974) surveyed eight of the 19 square kilometers in the map of Dzibilchaltún. The map includes 8,398 buildings plus other types of features. Using the method described above, I selected 15 out of 94 recorded wells listed on Kurjack's map to verify precision of registration and record feature measurements. I entered the geographic coordinates of each well from the project GIS into a Garmin GPSIII Plus navigational GPS data collector. In the field, I was able to successfully navigate to 14 of the 15 pre-selected wells. The margin of error in coordinates developed from the map and ground position ranged from a 4.5 meter maximum for one well to less than 1.0 meter, with the average at 2.3 meters. The single well that was not located most likely collapsed or was concealed by vegetation growth taking place over the 40 years since Kurjack's survey. Considering the level of precision I was able to achieve using this method, not only the 14 wells surveyed, but also the remaining 80 documented by Kurjack and others were incorporated into project analyses.

The GIS for this research is capable of adjacency spatial analysis of cultural and natural features. The design is a modified decision model after Marble (1994) and elaborated by DeMers (1997). The GIS software I chose supports vector-based topological analyses. Raster based data were converted to a vector format prior to development of spatial or attribute queries. The model permitted analysis of a wide variety of spatial and non-spatial physical and cultural data recovered from the landscape and existing reports. Topologically structured data facilitate both contiguity and connectivity analyses. Contiguity (Arnoff 1993) measures were employed to evaluate characteristics of spatial units and define contiguous areas having common water-management features and isolate probable relationships between settlements. Proximity measurements provided data to define norms for transportation distance and settlement location as they relate to natural water sources or cultural features that represent strategies to store or divert water. The GIS was also used to determine optimum routes of resource allocation for networks within the region. Spread functions were used to determine the dispersal of particular innovations from bases of origin. Intergraph MGE (Modular GIS Environment) and GeoMedia Professional 5.0; Research Systems ENVI 3.4; Bentley MicroStation SE; Total Data

Systems ForeSight 2.20, and Trimble Pathfinder Office 2.80 constitute the GIS environment used to process and analyze research data. Statistical analyses outside the GIS environment were accomplished in SYSTAT 8.0.

Prior to operations in the field, Universal Transverse Mercator coordinates, UTM's, for over 1000 site locations taken from Garza and Kurjack (1980), Dunning (1992), and a revised database provided by Edward Kurjack for sites listed in the *Atlas Arqueológico del Estado de Yucatán* were processed to construct a project base map and relational databases. Additional geographic coordinates for sites not included in the "Atlas" files were retrieved from the GEOnet Names Server on the NIMA (National Imagery and Mapping Agency) website. Thematic maps, provided by Instituto Nacional de Estadística, Geografía e Informática, INEGI, in Merida, Yucatán, were scanned and digitized for incorporation into the base map. Finally, remote sensing data for the region were processed and incorporated into the project GIS. By the time fieldwork began, site maps for several upper-ranked sites were prepared for field verification.

In addition to the preparations discussed above, standardized forms for the collection of spatial data were designed to insure that all required data were collected prior

to the close of each day's work. Discovering the relationships between spatial and non-spatial data is a principal goal of this study. Therefore every effort was made to insure the geographic coordinates of all features observed and artifacts collected in the field were recorded. The common link between spatial and non-spatial data is the "data file" or rover number. The Trimble GeoExplorer GPS data collector creates a unique rover file for each position as it is recorded in the field. After a day of collection, the data were downloaded directly into the project computer. While in the field the rover file number was recorded on each standardized form. At the time the data from the field collection forms were entered into the database, the rover file, (data file) was entered as well. The data from field forms was then linked to its true geographic position in the GIS.

Field Operations

Operation One: Archival Research

During a three-week period beginning January 23, 2001 and ending February 14, 2001, archival research was completed and data collected from unpublished archaeological reports, *informes*, and other project-related documents stored in the archaeological section files and libraries of INAH offices in

the states of Campeche, Quintana Roo, and Yucatán. Data were collected related to known hydrological features, buildings or their mounded remains, natural topography relevant to water catchments, prior archaeological work, and site chronology. I was assisted for the entire period by archaeologist Virginia Ochoa-Winemiller M.A. a doctoral student at Louisiana State University and a portion of the time by Jose Manuel Ochoa-Rodriguez a student from the Universidad Autonoma de Yucatán Facultad de Ciencias Antropológicas and Project Director of the Coba Archaeological Project. Site maps, sketches, site reports, and other documentation were photo copied or scanned into a laptop computer. Tiled images of scaled site maps were merged into mosaics and geo-referenced after coordinates for selected ground control points were collected in operations two through five. These maps were ultimately incorporated into the project GIS, digitized, and joined to non-spatial data in relational tables.

Operation Two: Upper-Order Sites

This operation provided data concerning the relationship between surface water, water management systems, and the development of Maya cities. Considering the physical environment of Yucatán, the often-expected observation is scattered small villages, patio clusters, or households spaced

across the landscape without a significant uninhabited periphery. The existence of clustered populations in northern Yucatán prompts questions about causal factors contributing to centralization and the development of stratified society in the Maya area. One possible explanation tested was resource circumscription (Carneiro 1970). Portions of the data collected address resource circumscription among the ancient Maya.

Twelve upper-ranked sites in the study area were surveyed during operation two lasting from February 15, through August 16, 2001 (Figure 2.1). Fieldwork for Operation two was initiated at Mayapan. The basis for survey at Mayapan was a topographic map of the ruins of Mayapan was completed by Morris R. Jones from 1949 through 1951 (Pollock et al. 1962). Maps and data were available for other upper order sites as well, including Chichén Itzá, Cobá, Dzibilchaltún, and Uxmal. Tasks included field verification of locations and spatial relationships between structures and water management features appearing on existing maps and sketches, GPS collection of geographical coordinates for principal structures, and notation of undocumented cultural or natural water features by type. When practicable and potentially informative, a foot survey of the site area was accomplished to estimate boundaries and document structures, groups, settlement areas and features not

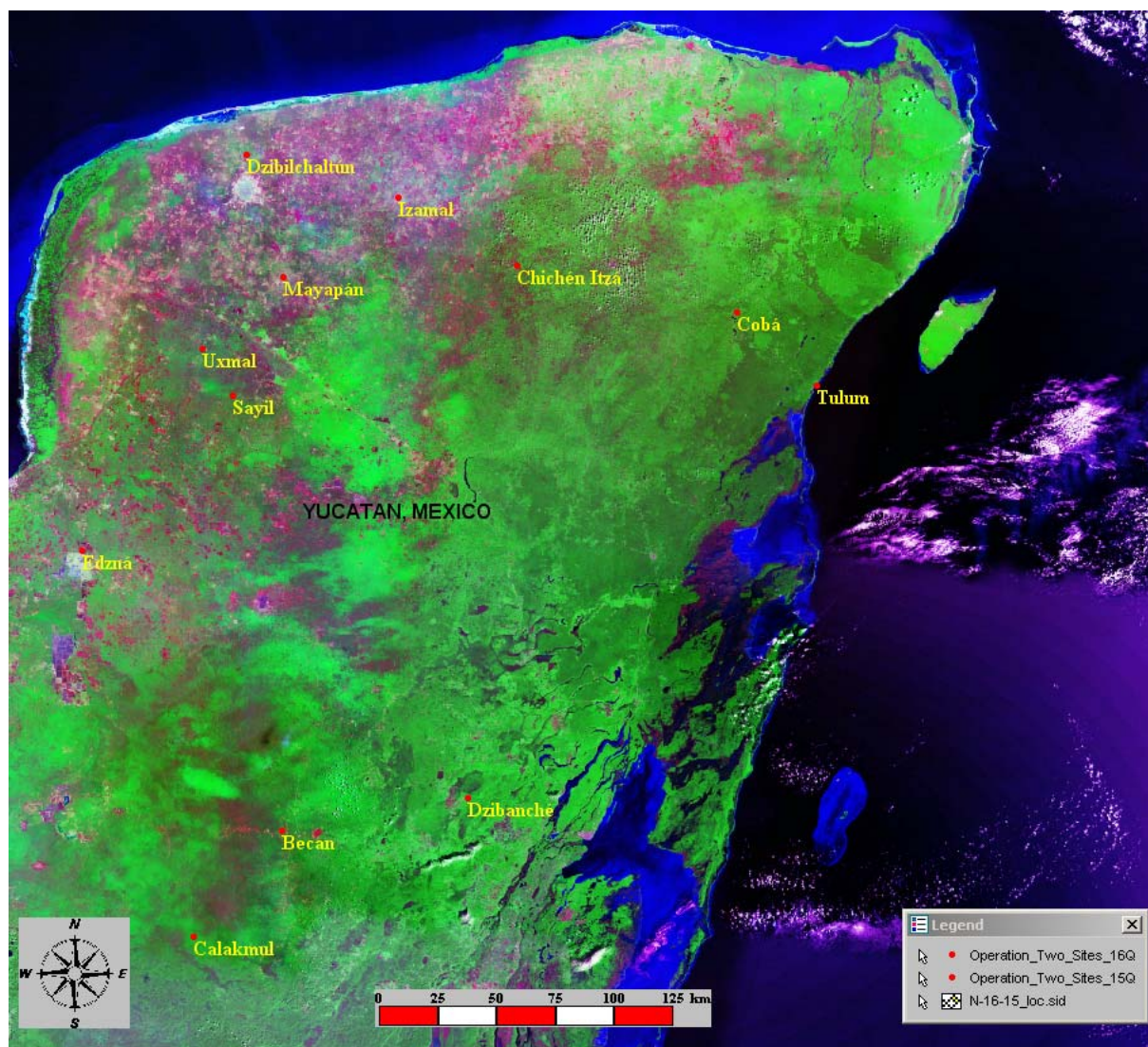


Figure 2.1 Upper-ranked sites in the study.

recorded in earlier investigations by others. Boundaries of sites were determined arbitrarily by interpreting the absence of contiguous structures or mounds for distances exceeding 250 meters as rural space, a method similar to Dunning (1992). In instances where no prior stratigraphic data were available, test units were excavated in wells, *chultunes*, *aguadas*, or

canals, to record form for comparison to existing classifications.

Operation Three: Physiographic Study

I began collecting operation three data on February 15, 2001 at the site of Aké, Yucatán. Aké, a second order site, was not originally included in this operation. A substantial portion of Izamal, the site originally included in operation three, is either nonexistent or underneath the modern town. By contrast, a substantial portion of Aké remains relatively undisturbed, except for the effects of the henequen industry in parts of its periphery. During operation three, one upper-ranked site from each of nine physiographic regions in México defined by Wilson (1980) was surveyed. Wilson's districts are illustrated in (Figure 2.2). For a complete description of characteristics used to define each district see Wilson (1980). Eight of the sites in this operation are upper-ranked sites also included in operation one. The additional information required for physiographic comparison was collected concurrent with operation one activities. In one district, Rio Candelaria, Pustunich was originally selected for study in this operation, but for reasons discussed below no data were collected. Therefore, any inferences regarding the impact of environmental conditions in the Rio Candelaria District are based solely on

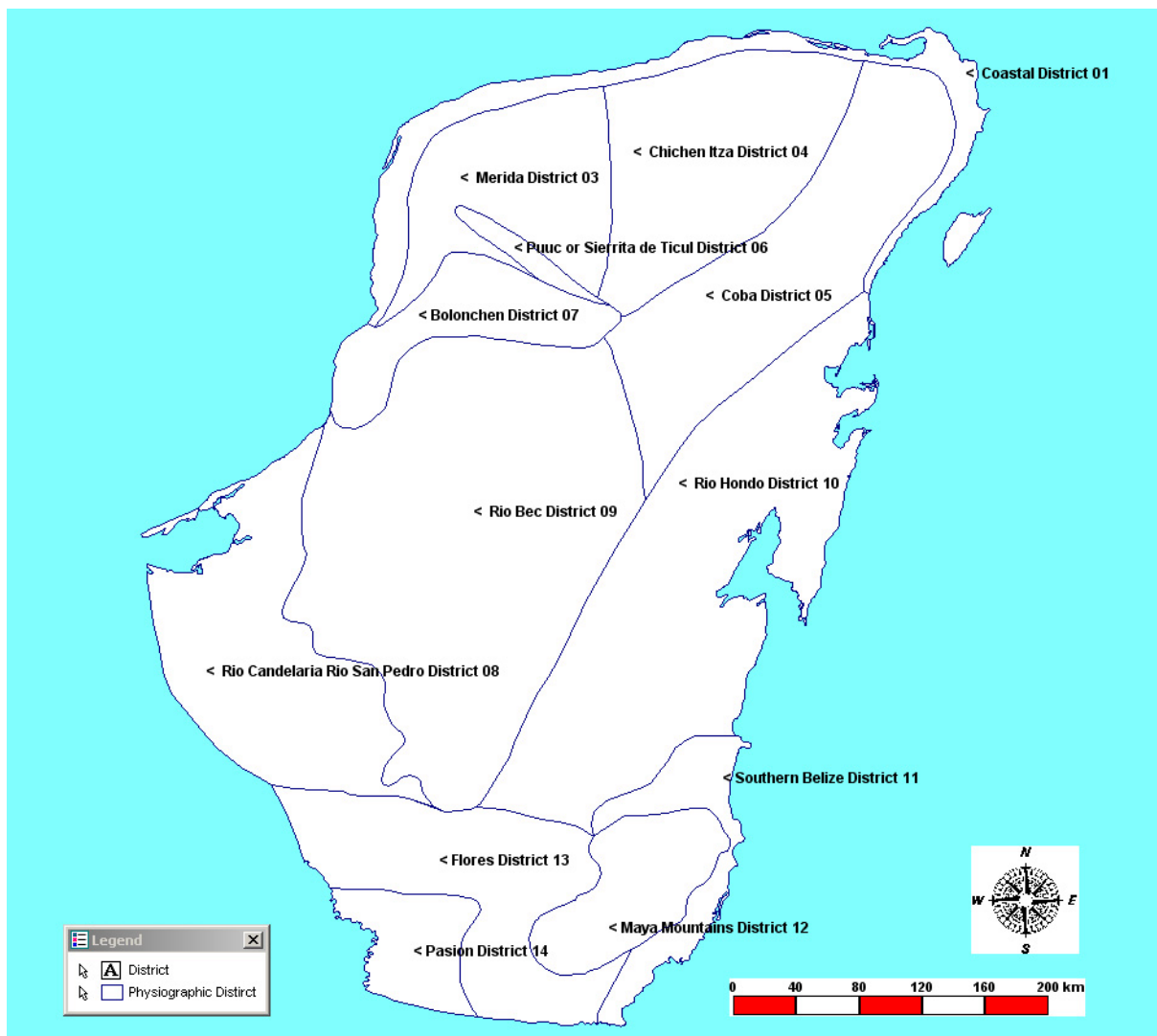


Figure 2.2 Wilson (1980) physiographic districts.

existing research. The project GIS enabled me to stratify site by physiographic region to identify correlations between site development, adaptive strategies, and environmental variation. Maya workers participated in foot survey, and provided information pertaining to the location of archaeological

settlement features and water sources. Examination of air photos, satellite imagery, and geological, topographic and hydrological maps aided ground survey efforts. Transects were mapped from site cores outward until no cultural features were found within the arbitrary 250 meter distance noted in discussion of operation three.

In addition to finding correlations between the unique nature of various physical environments and locational decisions, this operation revealed new evidence of water sources and conservation features, sheds light on a number of site-specific developmental sequences, and provided new data to supplement existing water-systems feature classifications. Surface collections were completed in order to construct individual site development sequences using hydrological features and position each site within its regional interaction sphere. Results from this operation, archival data, and information collected from third and fourth ranked sites formed the basis for conclusions regarding particular adaptive strategies and physiographic variation in the region. Operation three was completed August 16, 2001.

Operation Four: Lower-Order Sites

Shortly after arrival in Campeche to complete archival research, I discovered that military operations were being

conducted in remote portions of the state. Given that this fieldwork involved gathering geographic coordinates with a GPS data collector, I felt that military personnel and the growers might misinterpret my actions and motives. Therefore, plans to survey two of the nine lower-order sites in the original proposal, Pustunich 1 and Reforma Agraria, were abandoned.

From March 17 until August 16, 2001, a physiologically stratified sample of nine third or fourth order sites, one from each physiographic district in the region were surveyed. The settlements were GPS mapped using a method tested by Winemiller (2000a, b) in December 1998 at Cumtun, Yucatán, México. During the three-day feasibility test, four Maya workers provided by the Chichén Itzá Archaeological Project cut transects and cleared structures. After clearing, principal architecture, the mounded remains of structures, walls, causeways, and water features were GPS mapped. A sketch map of the site was drawn, and a ceramic surface collection completed during the field test as well. Subsequently, a corrected computer map was completed and incorporated into a GIS for analysis. The ceramics were analyzed to elucidate the relationship of Cumtun to Chichén Itzá; a first order site situated 5.5 kilometers to the southeast. The method employed by Winemiller during the Cumtun field test was similar to methods used by Dunning (1992)

in the Puúc area of Yucatán. Dunning's team cut transects across sites until settlement features became "discontinuous" (separated by distances greater than 100 meters).

During the survey, architecture and water collection or storage features were classified, GPS mapped, and incorporated into the relational databases. Operation four was designed, in part, to reveal variants in adaptive patterns that may be scale specific as well as environmentally specific. Social factors such as elite control of water resources should not be present at the less developed third and fourth ranked sites where activities were orchestrated at the individual, kin group, or communal level. Investigation at this scale of settlement informs us about specific adaptive strategies at the minimum residential unit, and cluster level. My expectations were that comparison of data from lower ranked sites with information gathered at higher order centers would reveal an access continuum extending from free at lower order sites to controlled resources in higher order contexts. Evidence discovered at Noh Pat that suggests this might have been the case.

Operation Five: Continuity of Regional Settlement

Operation five was designed to test whether or not the absence of sites in certain areas of northern Yucatán

represents research bias (insufficient investigation) or is indicative of physical and social pressures coming to bear on locational decisions. In addition to physiographic distinctions described by Wilson (1980), existing spatial data indicate the study area was culturally stratified into populated and unpopulated areas.

Bullard (1960) noted a clustered- dispersed settlement pattern in northeastern Petén, Guatemala. This pattern depicts settlement in parts of northern Yucatán as well. Concentrations of households occurred most often in the vicinity of present-day surface water sources or in areas where large expanses of level ground exist. Bullard's study also revealed a marked absence of sizeable uninhabited areas. His work suggested that access to surface water and suitability of land for agriculture were elemental considerations in settlement decisions. A combination of physical and cultural transformation processes precludes identification of hidden archaeological, architectural, and water management features on the landscape without the aid of tools such as remote sensing systems.

Prior to and during ongoing fieldwork, I interpreted Landsat Thematic Mapper(TM), multi-band / multi-polarized SIR-C radar, and air photos to define areas with the potential for water resources or terrain suitable for catchments but no

documented settlements. Methods for the interpretation of radar and Landsat TM imagery as it applies to archaeological research and hydrology have been discussed by several researchers (Adams 1980, 1982; Adams, Brown Jr. and Culbert 1981; Holcomb 1990, 1992, 1998; Lewis 1977, 1998; Lewis and MacDonald 1970, 1972; Lewis, Henderson and Holcomb 1998; Olsen 1985; Pope and Dahlin 1989, 1993; Pope, Benayas and Paris 1994; Winemiller 1998, 2000a, b).

The purpose of operation five, was to "ground truth" potential settlement locations identified in the remotely sensed data. Time and budget allowed for one attempt to visually identify potential settlement locations in remotely sensed imagery and subsequent foot survey to ascertain whether or not the classified area includes sites. During survey the location of mounds, structures, and water storage features were recorded, sketch maps developed, and surface collections accomplished. This operation addressed four issues, (1) the extent of research bias in the archaeological site inventory of northern Yucatán (2) the relationship between presence or absence of surface water or catchments and settlement, (3) the physical or social factors responsible for Maya avoidance of areas, (4) the archaeological application of various combinations of remote sensing data as tools to identify the

combinations physical features most favorable for human occupation. This operation was successful. The methods will be refined and tested in future projects.

Analysis and Laboratory Methods

Cataloging and analyses of data collected during field operations was an ongoing activity. Artifacts and ecofacts recovered by surface collection or excavation were routinely transported to and housed at the project office in Merida, Yucatán, Mexico where they were washed, marked, and catalogued. Following analyses, the collection will be turned over to one of the three local INAH offices having jurisdiction over the sites in the region. Ceramics, lithics, and ecofacts were analyzed and catalogued by Virginia Ochoa Winemiller and the author. Ceramics were classified as described by Rice (1987) using the Type-Variety System implemented by Smith Willey and Gifford (1960) based upon references for northern Yucatán regional ceramics including (Andrews V 1993; Ball 1977, 1979; Brainerd 1958; Kosakowsky 1987; Peraza Lope 1993; Rice 1987; Robles C. 1990; Sanders 1960; Simmons 1979; Smith 1971; Smith, Willey and Gifford 1960; Vaillant 1927). After classification, artifact data were entered into tables created in Visual dBase 5.7.

Processing of archival data was completed in Merida, Yucatán where the project was based. Geographic coordinates, collected with a Trimble GeoExplorer III data collector, were stored as coordinate files and downloaded after each day of ground survey into the project computer. Completing real-time corrections in the field was impractical, so post processing operations, including calculation of differential corrections, were accomplished in the office using base station data provided by INEGI in Merida, Yucatán and downloaded data from base station sites on the internet. Corrections were also applied to backup data sets using base data from English Turn, Louisiana and Edgemont Key, Florida. After differential corrections were applied, point features for positional data were plotted in maps with Trimble's Pathfinder Office software. To insure accuracy and precision, preliminary maps were constructed after each day in the field. Discrepancies were noted, the affected positions were discarded and a second set of coordinates were collected the following day. Verified Pathfinder maps were exported as MicroStation design CAD and ArcView shape files and imported into Intergraph's MGE or GeoMedia Professional 4.0, and later version 5.0, for feature definition and attribute assignment. Tables were exported in Pathfinder to dBase format then imported into Excel 2000. In

some instances platforms and structures were mapped using an electronic total-station. The geographic coordinate of a principal datum for laser-mapped structures was established with a GPS data collector. All other positions were recorded as points of easting and northing and stored in a data collector. Laser coordinate files were be downloaded directly from the field data collector into the project computer and T.D.S ForeSight for plotting and processing.

Various statistics were employed as tools for discovery and planning. The GIS is capable of providing measured distances between projected geographical coordinates of all feature types. Point pattern analysis and quadrat were applied to site level point data using various physically and culturally defined boundaries to determine locational randomness. Where data were sufficiently developed, the chi-square statistic was used to determine the extent of correspondence or association between quantifiable. Attribute and Spatial GIS queries were employed to pinpoint associations among various types of water sources and improvements, architectural features, and settlement types. All spatial and non-spatial project data were integrated using joins in GeoMedia Professional 5.1. The resultant features and tables were output to a final version Access database.

CHAPTER 3

LAND, WATER, AND ADAPTIVE STRATEGIES

The Yucatán Platform and Water

During the spring, summer and fall of 2001, I conducted investigations at 31 archaeological sites located across the Yucatán Peninsula. The area of study includes the portion of Yucatán within the political boundaries of modern day Mexico between 18° 6' North and 21° 40' North and 86° 42' West and 91° 30' West. The research was designed to test the significance of both physical and cultural environmental factors on ancient locational decisions. Table 3.1 lists the sites included in the study, site numbers for this project, Universal Transverse Mercator (UTM) Zone, UTM coordinates, geographic coordinates, site rankings according to (Garza and Kurjack 1980), and contemporary municipal affiliation.

Language, in particular lexicon, reveals the significant aspects of culture that enable a society to thrive in a variety of environments. The importance of water to the Maya is clearly evident in their words for water and places where water is found. *Mayan* toponyms are frequently derived from the particular hydrological characteristics of places. For example,

Table 3.1 Sites and Location

SITE	ZONE	LATITUDE	LONGITUDE	RANK
Acanceh	16Q	20:48:50.274	-089:27:06.975	3
Acanmul	15Q	19:54:05.124	-090:19:29.019	3
Akalchen Group	16Q	20:42:32.734	-088:32:45.316	NR
Aké	16Q	20:56:52.381	-089:18:08.053	2
Becan	16Q	18:30:59.030	-089:27:59.256	1
Calakmul	16Q	18:06:28.971	-089:48:19.373	1
Chicana	16Q	18:30:24.461	-089:30:35.525	3
Chichén Itzá	16Q	20:40:30.958	-088:34:10.825	1
Cobá	16Q	20:29:41.020	-087:43:54.146	1
Cumtun	16Q	20:42:23.320	-088:37:03.613	NR
Dzib Chaac	16Q	20:25:44.679	-088:54:08.707	NR
Dzibanché	16Q	18:38:17.299	-088:45:33.955	1
Dzibilchaltún	16Q	21:05:43.085	-089:35:56.114	2
Edzná	15Q	19:34:58.872	-090:13:37.718	1
Ixbaac Group	16Q	20:26:06.473	-088:46:01.242	NR
Isla Cerritos	16Q	21:33:46.697	-088:16:50.372	4
Izamal	16Q	20:56:00.135	-089:01:20.242	1
Kohunlich	16Q	18:25:22.035	-088:47:38.919	2
Mayapán	16Q	20:37:43.396	-089:27:41.132	2
Noh Ichmul	16Q	18:39:44.425	-088:12:45.739	3
Nohpat	16Q	20:18:49.022	-089:42:12.049	3
Sayil	16Q	20:10:31.274	-089:39:07.871	2
Tulum	16Q	20:12:56.239	-087:25:40.453	2
Uxmal	16Q	20:21:27.820	-089:46:09.165	1
Xcambo	16Q	21:18:43.177	-089:21:11.371	4
Xcaret	16Q	20:35:24.774	-087:06:06.184	4
Xelha	16Q	20:18:57.789	-087:22:17.990	3
Xpuhil	16Q	18:30:42.206	-089:24:31.119	3
Yulá	16Q	20:36:56.311	-088:34:12.076	4

Chichén Itzá is derived from *Chi* (meaning mouth, border or edge) and *ch'e'en* (meaning well), "mouth of the well of the Itzá" in *Mayan*. Moreover, *Ch 'e 'en* is the ninth calendar month in the *Ha'ab*, the Maya 365 day year. Where practicable, I refer to the various types of hydrological features found throughout the region by their respective *Mayan* referents to call attention to the role water played in the daily lives of the ancient Maya.

The word "karst" is German and derives in part from the Indo-European word "kar" meaning rock. Karstification indicates and is most often associated with the development of sinkholes and other solution features in areas formed of soluble limestone beds. Sinkhole or sink designates a hole or depression formed by sinking land surfaces where underlying rock formation has been removed by circulating water. The Serbian word "doline" meaning little "dole" or valley, is often used to refer to a variety of features in karst areas. Monroe (1970) defined dolines as basins or funnel-shaped hollows ranging in diameter from a few meters to a kilometer and from a few to several hundred meters in depth. Furthermore Monroe divided dolines into two major types, solution and collapse dolines. Solution dolines are formed by solution of limestone

surfaces and collapse dolines are the results of the collapse of surface material over caverns formed by solution processes. According to Stringfield and LeGrand (1969), sinkholes in the Yucatán Peninsula can be divided into three general types, Monroe's solution and collapse dolines plus *cenote*-type that is formed by collapse of the roof of a cavern bed by bed in thinly bedded limestone. Ultimately, a steep or nearly vertical-sided sinkhole up to 30 meters deep and hundreds of meters wide is formed when the collapse reaches maturity at land surface. There is an intermediate stage where a small opening appears at the apex of the bell-shaped collapsing strata. Several of the *cenotes* surveyed for this paper were in intermediate stages of development. Many of the *cenotes* of Mayapan are accessible intermediate stage *cenotes*. Funnel-shaped sinks form if thick layers of unconsolidated material overlay the limestone (Stringfield and LeGrand 1974).

Solution features predominate the landscape of the Yucatán Peninsula and rainfall is highly seasonal. Rainfalls that quickly vanish beneath the ubiquitous exposed bedrock and thin soils of the peninsula provided the water, and were essential for survival in the peninsula. In portions of the northern and central peninsula, the surface is pitted with numerous sinks. Saltwater encroaches on the highly permeable limestone of the

Yucatán Peninsula from three sides. The extreme permeability of the sedimentary limestone permits rapid infiltration of rainfall and a rapid movement of water through a system of caverns and subterranean streams ultimately discharging into the oceans.

An extensive body of sea water underlies much if not all of the peninsula (Back and Lesser 1981). Fresh water forms a floating lens (perched aquifer) varying in thickness from approximately 40 to 70 meters inland depending upon seasonal rainfall levels to nearly zero at the coast (Back and Hansh 1970, Back and Lesser 1981; Doehring and Butler 1974; Stringfield 1974). A zone of highly corrosive brackish water separates the freshwater lens from the saltwater layer in a zone known as the halocline. Through time, successive periods of sea level rise and fall caused the brackish zone to dissolve solution channels and create many subterranean chambers and *cenotes*, collapsed dolines that reach depths below the phreatic (Back and Hanshaw 1970, Back et al. 1986). In addition to transformations caused by activity within the brackish zone, meteoric water is responsible for many of the features and facilitated the dissolution of sub-*sascab* strata and process of diagenesis converting limestone to dolomite. Throughout much of the northern portion of the peninsula, a layer of *sascab*

representing the active solution front underlies the uppermost, hardened layer of limestone. Bedrock underlies the *sascab* layer. Variability in the composition and thickness of the caprock and *sascab* layer throughout the region provided opportunities and in some way might have limited the adaptive options available to the ancient Maya. This variability produced noticeable areal differences in the techniques used to construct *chultunes* and excavate wells.

Hydrological Features

While describing the Maya view of life, Redfield (1941) advanced four "chief terms" to describe the terrestrial world: "...the bush, the *cenote*, the village, and the milpa". He considered the *cenote* the most important of all natural features to the Maya, acknowledged their sacred place in Maya culture, and associated them with the *caac'o'ob*, the rain gods (Redfield 1941). This idea is supported by my own experiences during a Cha Chaac, or rain ceremony observed in June 2001 near the modern-day village of San Felipe Nuevo. While blessing the altar, representing a conceptual model of the milpa and Maya world, the *h'men* Maya priest prayed to the *caac'o'ob* to bless all the local *cenotes* and *rejolladas* or *kom'o'ob* by name and to bring rain to the village milpa. Redfield (1941) was not the

first to suggest that *cenotes* determined the position of human settlements in the Yucatán Peninsula. West and Augelli (1966) considered the round "steep-sided" hollows, called *cenotes* by the local Maya, to be the most common landforms, and the main sources of water in Yucatán. He was fascinated by the *cenotes* and *rejolladas* of the Yucatán and considered them to be significant in the lives of indigenous peoples both in the past and present (Personal communication 1998).

Centuries before Redfield and West, other explorers, missionaries, and soldiers described the land and water in the world of the Maya. Bernal Díaz del Castillo, a soldier in the armies of Pedro Arias de Avila and Hernando Cortez, as well as Friar Diego de Landa, a Franciscan missionary, who arrived in Yucatán in 1549 to convert the indigenous savages to Christianity, wrote first-hand accounts of life in the New World (Díaz del Castillo 1956; Diego de Landa 1938).

Bernal Díaz del Castillo described the first expedition of Hernández de Córdova to explore the coast of Yucatán. He originally departed Spain in 1514. Later in life, del Castillo related his account of hazards for unwary travelers in a country where fresh water was difficult to find. "We went ashore near the town which is called Campeche, where there was a good pool of water, for as far as we had seen, there were no

rivers in this country" (Díaz del Castillo 1956). After a skirmish near Champoton were the explorers stopped to fill their leaking water casks from one of two rivers along the coast de Cordova's men were forced to flee without their precious water. Díaz de Castillo recounted, "...our greatest trouble arose from the want of fresh water, for owing to the attack made on us and the haste with which we had to take the boats, all the casks and barrels which we had filled with water were left behind" (Díaz del Castillo 1956).

For Friar de Landa the unique rocky environment of the peninsula was apparent. He described the Yucatán as a place of many stones.

Yucatán is a land of less soil than any I know, being all live flat stones with very little earth, so that there are few places where one can dig down a fathom without meeting great banks of large rocks. The stone is not very good for fine carving, is hard and coarse; but such as it is it has served to produce the great number of buildings (de Landa 1978).

Diego de Landa cited the value of stone architecture to the ancient Maya and their accomplishments as the wealth of Yucatán.

If the number, grandeur and beauty of its buildings were to count toward the attainment of renown and reputation in the same way as gold, silver and riches have done for other parts of the Indies, Yucatán would have become as famous as Peru and New Spain have become, so many, in so many places, and so well built of stone are they, it is a marvel... (de Landa 1978)

Friar de Landa was the first European to describe in detail the deep waters of the Sacred Cenote at Chichén Itzá and its associated temple. He argued that (de Landa 1978), nature "acted differently" in Yucatán than in other parts of the world, and documented the nature and diversity of water resources in various parts of the peninsula and the significance of water in the lives of local inhabitants.

According to the wise, one of the things most needed by man is water, without which the earth cannot produce its fruits or man live. Yucatán lacks the abundance of rivers to be found in the neighboring countries, having only two; one of these is the Rio de Lagartos, which enters the sea next to a headland, and the other is that of Champoton; both being salty and of bad water. God provided many choice water sources, some natural and others brought out by industry. In this respect nature has acted differently in this country from the rest of the world, where the rivers and springs flow above the ground, whereas here all run in secret channels underground. As we have been told, the entire coast is full of springs of sweet water, rising in the sea, and from many of which one can get water, as I myself have done, when the ebb tide has left the shore dry.

Inland God has provided various breaks in the natural rock, which the Indians call *cenotes*, cut and reaching down to the water; at times there are below furious currents so as to carry off cattle that fall into them; all these go out into the sea, and from them the above springs come. These *cenotes* contain fine water and are a great sight, for some of them are of cut natural rock clear down to the water; others have mouths that God created or were caused by the accidents of thunderbolts (such as often fall), or in other ways. The people who got to these *cenotes* drank of them, having no wells, or very poor ones due to their lack of tools. Now however we have given them work at making good wells...

The Indians living toward the sierra, needing to have their wells very deep, are accustomed to gather the rain water for their homes in that season, in great cavities in the rocks because very heavy rains come then, with much thunder and lightning at times. (de Landa 1938:93-94)

Although John Lloyd Stephens (1988) noted an apparent scarcity of water on his first expedition to Uxmal in the Puuc area of Yucatán, he ultimately documented the diversity of natural and artificial sources of water found throughout the peninsula. He noted several *chultunes* at Uxmal that he believed functioned as cisterns for water storage. On a later visit to the site Stephens speculated about the intentions of the founders, the function of *chultunes*, and the artificial nature and adaptive significance of the *aguadas* found at Uxmal and other sites across the peninsula.

Who built it, why it was located on that spot, away from water or any of those natural advantages... (Stephens 1988:36).

Within the whole circumference there is no well, stream, or fountain, and no water, except the subterraneous chambers before referred to; which, supposing them to have been intended for that purpose, would probably not have been sufficient, however numerous, to supply the wants of so large a population. ...we were not long in satisfying ourselves that the principal supply had been drawn from *aguadas*, or ponds, in the neighborhood (1988).

...*aguadas* had become to us interesting objects of consideration. Ever since our arrival in the country, we had been told that they were artificial, and, like the ruined cities we were visiting, the works of the ancient inhabitants (Stephens 1988: 259).

Upon further investigation of the *aguada* at Macobá, Stephens noted a stone lining, several stone-lined wells and hundreds of *casimbas*, pits for water infiltration. A local inhabitant attested to effectiveness of these modifications in times of drought. He related an incident during a local drought when thousands of people traveled from villages as far away as 18 miles to draw water from the reservoir (Stephens 1988). At Rancho Jalal, Stephens noted local accounts of wells and *chultun*-like features, known as *buk'tes*, in the bottom of an *aguada*. After clearing the *aguadas*, wells like those found at Macobá and *buktes* penetrating the lining of the *aguada* provided sufficient water to last through the entire dry season, while the basin remained dry.

Shattuck (1933) noted modern use of *aguadas* as sources of water for local inhabitants. Shattuck pointed out that many *aguadas* before cleaning were filled with centuries of accumulated silt and mud. The *aguadas* observed during fieldwork were all situated in depressions and were surrounded by low hills. During the rainy season, frequent tropical rains wash large amounts of organic material, soils, and silt from the surrounding hillsides into these shallow depressions. Maintaining *aguadas* as sources of water for consumption must have been a constant struggle for the Maya. I excavated an

alignment of stones lining the perimeter of an *aguada* at Uxmal. These alignments are found in many *aguadas* and might have provided convenient access as well as prevented silt and other materials from filling the depression and rendering the reservoir ineffectual.

Huchim Herrera (1991) excavated a *buk'te* in *Aguada Chen-Chan* at Uxmal, Yucatan. Stephens suggested that *buk'tes* were constructed to take advantage of water trapped in saturated clays and soils beneath the stone or impermeable-clay lining the *aguadas*. The feature permitted ground water to filter through permeable walls into a cavity, effectively extending the depth of *aguadas* to the bottom of *buk'tes* (Huchim Herrera 1991; Velazquez Morlet et al. 1988).

According to Stephens (1988), at Bolonchen, ancient wells failed in the absence of regular rainfalls. The dry period usually lasted four to five months, forcing the inhabitants to collect and transport water from Bolonchen Cave several miles from the village. Stephens explored the cave and described his descent along an estimated 1450 feet of steep shifting corridors and vertical shafts to a pool of water found at a depth of 450 feet below the surface. The pond was known to the locals as *chacka*, red water in *Mayan* (Stephens 1988). Stephens (1988:278-279) also documented the great open *cenotes* such as

those found at Chichén Itzá and the more obscure cave-like *cenotes* of Mayapan (1988: 77). For Stephens, the significance of water sources to the Maya and their settlements was clear.

Holmes (1895a), a curator for the U.S. National Museum, likened the Yucatán in the dry season to a "waterless and forbidding desert" having fractures, channels and a porosity that rarely permitted formation of reservoirs of surface water or springs even in the rainy season. According to Holmes, over time, similar processes in Yucatán, driven by vast underground streams, formed caverns, sinks, and "cistern-like pits." He was describing the great *cenotes* of Yucatán, which he also called wells. For Holmes (1895a), the unique environment of Yucatán left its mark on the people and their art. Moreover, he argued that the earliest inhabitants, the pioneers, took possession of the *cenotes* or wells and built their settlements. Holmes documented depressions at the site of Chichén Itzá that he described as "dead wells." These were the ubiquitous *rejolladas* found throughout much of north central Yucatán. In a later publication, Holmes (1897:204) described in detail the now famous aqueduct of Palenque in the modern day state of Chiapas.

Mercer (1975) while exploring twenty-nine caves and countless *haltunes*, recognized that the early Maya could not have populated northern portions of the Yucatán without a

knowledge of the location of subsurface water. Early settlers examined every cave for access to a permanent source of water and settlements grew up next to these valuable resources (Mercer 1975). Mercer's early work described the two waters of the Maya *ha'* and *zuhuy ha'* as well as the practical and the symbolic use of *cenotes* and *aktuns* as resources providing water for human consumption, ritual, and sacred space for burial chambers. Archaeologists from the University of Alabama working at the site of Xkukican, Yucatán, Mexico discovered ceramics, artifacts, and burials in an *aktuns* that functioned as a place for sacred ceremonies, a tomb, and a resource for consumable water (Cottier 1967; Nielson and Sheldon 1971). At Xkukican, Maya burials were found in pools of water within certain apparently sacred chambers with evidence suggesting ritual activity (Sheldon personal communication 2003)

For heuristic purposes, the distinction is made between *cenotes* and *aktuns* based upon whether or not the source had water and was fully or in part open from above or completely subterranean. Water sources with any degree of open exposure are considered *cenotes*. Subterranean sources are considered *aktuns*. This classification is consistent with modern Maya perceptions provided by several informants I interviewed throughout the region. Some Maya refer to pools of water in

aktuns as *akalchens* meaning dark well. Some scholars (Rissolo 2001) for reasons related to specific research interests or geographic regions consider subterranean pools of water to be *cenotes*.

Clearly, *aktuns* provided the ancient Maya with the water they needed to survive when the tropical climate failed them. The first inhabitants on the peninsula would have sought out *aktuns* for shelter as well. Thompson (1897a) described the famous cave at Loltun, a site believed by some (Gonzalez Licon 1986; Millet C., Velazquez and MacSwiney 1978; Velazquez Valadez 1980, 1981) to have sheltered early human inhabitants on the peninsula.

The Yucatán and Possibilities

Environmental Districts: Dividing the Region

Wilson's (1980) physiographic regions or districts provide a generalized idea about the diversity in the region. He divided the Maya area into fourteen districts (Figure 2.2). Sites selected for this project are located in nine of Wilson's fourteen districts. His definitions form a generalized basis for inferences about the impact of physical variation upon settlement locations and adaptive strategies pertaining to water management. In addition to delimiting the fourteen

physiographic districts in a GIS environment, additional layers were constructed to provide a more-detailed characterization of environmental factors that might have influenced ancient Maya locational decisions. Data were taken from 1:1,000,000 and 1:250,000 scale thematic maps provided by INEGI, Mexico's Instituto Nacional de Estadística Geografía e Informática. The detailed environmental profile includes climate, evapotranspiration, geology, surface and sub-surface hydrology, rainfall, soils, vegetation coverage, modern land use, and static water levels. Depth to static water levels and information regarding water properties were provided by the Comisión Nacional del Agua for the States of Campeche, Yucatán, and Quintana Roo. Several layers of Landsat Thematic Mapper data are included in the GIS. These include full scenes as well as subsets representing site-specific areas. NASA provided the Landsat TM data for the entire region of study through the EarthSat government-sponsored Data Buy Program in conjunction with the National Science Foundation. Other layers of environmental data include orthorectified air photos in 1:75,000 and 1:4,000 and 1:2,500 scale panchromatic air photos provided by INEGI, and various site maps from The Carnegie Institution of Washington, D.C., and other publications. By reconstructing the physical environment in the GIS environment

and combining these data with field observations, I was able to compare the diverse variety of physical water features found throughout the Yucatán Peninsula with archaeological and ethnographic data on the Maya and their ancient settlement locations. Many of the natural water features derive from the Yucatán's unique karstic environment.

Rivers and Drainage

The region of study is situated in three of the five major drainage zones, the Caribbean, Gulf, Karstic, Lacustrine, and Pacific defined by Hammond (1998). Although several sites are located in the Gulf and Caribbean Drainage Areas, none are close to major rivers. The Rio Usumacinta, Rio SanPedro, and Rio Candelaria, all located in the Gulf Drainage Area, flow outside of the southwestern border of the region. The Rio Champoton flood plain lies north of the Rio Candelaria within the study area, but no sites along its banks were investigated. The Rio Hondo on the southeastern border of the study area in the Caribbean Drainage Area separates Mexico from Belize as it flows north-northeast eventually emptying into Chetumal Bay. Dzibanché, *Tzi'banche* in Mayan the only site in the study near a river, is located along the floodplain of the slow-moving Rio Escondido in southern Quintana Roo, Mexico and surrounded by *bajos*, and low hills. The Rio Escondido provides water to the

Aguada de los Patos, a large *aguada* that covers an area of approximately one-quarter of a square kilometer 215 meters east-southeast of the Dzibanché Group.

Karstic Processes, *Haltunes*, Caves

Most of the sites in this paper are found in the Karstic Drainage area. The drainage covers the largest part the northern peninsula and consists of a karst limestone solution surface having red soils derived from limestone (West 1964). A major portion of the coastal region is of Pleistocene age. A section of the extreme northwestern coast is recent exposure. The northwestern third of the peninsula is formed by a tilted horizontal Pliocene and Eocene strata of limestone, dolomite, and gypsum with elevations approaching 40 meters above sea level (Figure 3.1). To the south and southeast, the Eocene and Miocene deposits form a hilly surface rising to approximately 130 meters. Much of the northern pitted-karstic plain is naturally divided from a southern hilly-karstic zone by a ridge, the *Sierrita de Ticul*, elevated approximately 50 meters above the surrounding terrain. South of the *Sierrita de Ticul*, folded Eocene limestone forms rows of linear ridges in the northwest near Campeche, an area known as the *Puúc*, and swampy swales in the southeast that follow a northeast to southwest

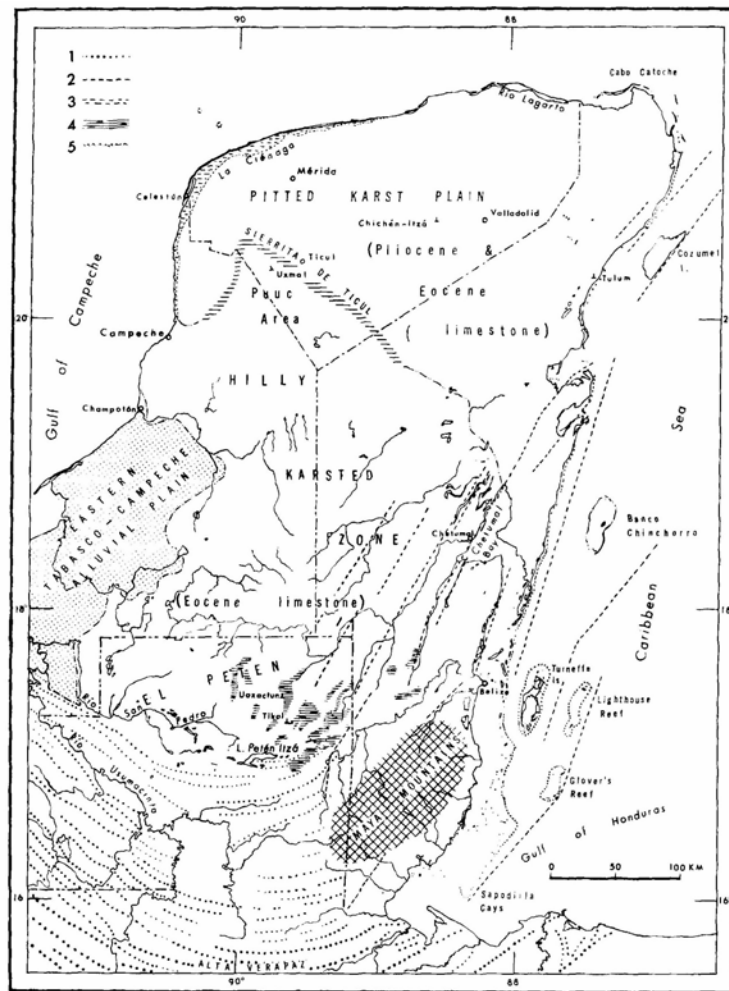


Figure 3.1 Geology of the Yucatán Peninsula after West (1964: 71)

trending fault pattern. Near Campeche these ridges rise to 350 meters.

In the northern Karstic Drainage, there are no surface streams. Sedimentary rock, such as limestone, is inflexible and easily cracks when supported unevenly. Thus, a major portion of the Yucatán shelf contains extensive joints, fractures, and faults caused by uneven stresses produced by uplift, solution

effects, and erosion (Driscoll 1986). Rainwater percolates through surface rock following crevices, joints and fractures to form underground caverns and rapidly moving streams. Reservoirs created through these processes provided the ancient Maya with water for consumption. Although much of the northern zone lacks surface water, areas where water sources lie near the surface are relatively abundant.

Three closely related and often interchangeably labeled naturally occurring water features are *cenotes*, *haltunes*, and *aktuns* that lead to pools of water. All these features are the result of karstic processes and provide access to either exposed or subterranean pools of water. *Aktuns* and *cenotes* are well documented for the modern States of Yucatán and Campeche.

Numerous faults and fractures extend south-southwest from Laguna Conil on the northern coast of Quintana Roo to the Maya site of Coba. The geology in this area provides sufficient relief for the formation of numerous lakes, and bajos. The area is geologically referred to as the Holbox fracture zone a zone of linear depressions and swales that follow an underlying system of horst and graben features within horizontally-bedded Tertiary carbonates (Tulaczyk et al. 1993; Weidie 1982, 1985). In this region, as well as most coastal areas and the level portions of the peninsula, the phreatic is relatively close to

the surface, making access to water less difficult than in others such as the Puúc area of southern Yucatán. For this reason, finding water in this area most likely was not problematic for the ancient Maya. The region, like other parts in northeast and southeast portions of the peninsula, is dotted with lakes, wetlands, and caves that were considered favorable places for early habitation. Rissolo (2001:47-48) cited the difference between the hydraulic physiology of Quintana Roo and the States of Campeche and Yucatán as the basis for functional differences between caves, *cenotes* and settlement location. Essentially, in Yucatán and Campeche, settlements depended on these features as "last resort" or significant sources of water for consumption. Caves in the Yalahau region of Quintana Roo were controlled spaces having limited access for ritual use (Rissolo 2001).

By comparison to the hundreds of sites and features known to exist and documented in Yucatán and Campeche, only recently have the relatively few caves been documented in Quintana Roo. Much of the information from the Holbox is the result of site-specific studies and general areal surveys. Notable exceptions include the Yalahau Archaeological Project, an ongoing project directed by Fedick of the University of California, Riverside, Ramon Piña-Chan and Muller's (1959) Atlas of Quintana Roo, and

Rissolo's (2001) dissertation on cave use in the Yalahau Region.

Evidence for early occupation has been reported for Loltun Cave in Yucatán (Thompson 1897a; Velazquez Valadez 1980). Findings at other sites were considered evidence of Archaic Period use of caves and *cenotes* as sources of water (Andrews and Corletta 1995; Coke, Perry and Long 1991). Still others have written about the significance of caves in the peninsula (Mercer 1975; Rissolo 2001). Rather questionable dating methods employed by Velazquez for Loltun Cave in northern Yucatán, the absence of radiocarbon dates and use of known dates for faunal and floral remains in strata where artifact associations were not demonstrated and a valid depositional sequence verified, render the notion that the cavern was occupied or used by early inhabitants of the area uncertain at best.

The karst and semi-karstic geology of the peninsula was of great importance to the ancient Maya. Throughout a major portion of the region, the phreatic zone is beyond the reach of ancient Maya water-well technology. In some northern districts the aquifer is a few meters beneath the surface and is easily accessible by excavating shallow wells, or exits through natural springs. In some places and some instances, nearly horizontal shafts lead directly to subterranean pools not far

beneath the surface. This is the case for a pool of fresh water observed under Structure 35 at Tulum. Farther inland, a zone of *cenotes*, known to the modern inhabitants as the Zone of *Cenotes*, exposes the phreatic to inhabitants. Today, this geologically formed pattern provides a level of predictability concerning the location of ancient Maya settlements, karstic topography and naturally occurring water resources.

According to Gill (2000), the Maya excavated wells to a maximum depth of approximately 23 meters. During fieldwork, the deepest well measurement taken only reached 14.5 meters. At Chichén Itzá, the aquifer is approximately 26.5 meters below the ground surface at *Cenote Xtoloc* and *Cenote Sagrado*. In the hill country beyond the Zone of *Cenotes*, caverns provided the only natural access to reach freshwater. Into historic times, the local residents of Bolonchen, approximately 80-kilometers north-northeast of the modern city of Campeche, collected water from caves when their water systems failed. Stephens and Catherwood (1988) documented and illustrated the difficulties of collecting water from caves. As Gill (2000:258) pointed out, for much of the peninsula, water management by necessity emphasized collection over diversion and source over allocation. An elemental axiom, noted by many scholars of the ancient Maya, applies to settlements in this portion of the

region, "where water was found, the Maya settled." In other areas, the Maya developed adaptive strategies to store or extract water for consumption.

Sea estavellas, Petens, and Springs

In many areas near the coast, the groundwater head often exceeds that of the Gulf or sea, forcing the salt-water/fresh-water interface to move offshore (Driscoll 1986). Sea estavellas are submarine openings in the sea floor where freshwater flows outward from groundwater heads into coastal lagoons or offshore waters (Stringfield 1974). These features are essentially underwater cenotes. Outward flow from sea estavellas is often seasonal. In these instances, several months after the onset of the dry season insufficient pressure on the freshwater head might permit seawater to encroach in the upper part of the aquifer.

At the site of Isla Cerritos, an island situated less than one kilometer off the northern Yucatán coast, sea estavellas known as *ojos de agua* by the local inhabitants flow into the shallow Gulf waters. The likely potential for seawater encroachment during the dry season suggests that estavellas might not have been reliable year-round sources of water for consumption. Therefore other adaptive strategies, such as construction of cisterns or transport of water from mainland

springs, might have been necessary for survival in these locations as well. However, no evidence of water storage features can be found on the island today. This does not rule out the possibility that the Maya constructed shallow cisterns. Considering this area experiences substantial rainfall, the construction of some type of retention area, possibly platform cisterns or shallow lined *aguadas* is highly likely. However, the area is exposed to frequent hurricane activity that has the potential to destroy archaeological evidence. The ancient inhabitants most likely collected water from sea estavellas between the island and the coast and a *Peten*, a spring that surfaces near the coast often in a shallow estuary, located inland near the site of Paseo de Cerros on the Yucatán coast due south of Isla Cerritos (Andrews: personal communication 2001). *Petens* contain ceramic evidence of their use as sources of water. At the coastal site of Xcambo, seven *ojos de agua* (springs) were observed evenly distributed across the site (Figure 3.2). These springs most likely supplied the ancient inhabitants. A *peten* was found about one kilometer from the site core as well but no artifacts were recovered.



Figure 3.2 *Ojo de agua* or spring at Xcambo, Yucatán, Mexico.

Rejolladas and Cenotes

The local inhabitants of the Yucatán peninsula label funnel-shaped dry sinkholes or dolines *rejolladas* in Spanish, *kom'o'ob* (plural) or *K'om* (singular) in *Mayan*. The term means lower section of land, a hole or basin, or valley between two mountains. These depressions often reach depths of 20 to 30 meters below the surrounding terrain. Over time, materials transported by heavy sub-tropical rains produced an

accumulation of rich soils composed of organic material and bits of limestone at the bottom of *rejolladas*. Today, the Maya regard *rejolladas* as highly desirable locations for their horticultural plots and seek them out. Some *rejolladas* have caves at their bases leading to subterranean pools of water or springs surfacing underneath collapsing ledges. These pools are considered by the Maya to contain sacred water, known as *zuhuy ha'* (virgin water or first water from the well) in Mayan. In the *Rejollada* Thompson, at the site of Chichén Itzá, I observed several limestone *metatitos* (miniature *metates*) or *pilas* (stone querns), one placed on top of a column near a sacred pool and others positioned on the ground to collect drops of *zuhuy ha'* dripping from the overhanging ledge (Figure 3.3).

If water is pumped from a sacred cave or open pool at the bottom of a *rejolladas*, or drawn from a *cenote* through a *brocal* or well curb-stone constructed at a surface orifice, a modification in terms of Maya perception transforms the *cenote* into a *ch'e'en* or well and the water is no longer considered to be sacred *zuhuy ha'* but instead *ha'* water for consumption.

Likewise, the Maya can conceptually change water *ha'* into sacred water *zuhuy ha'* with prayers much like Christian clergy transform wine into blood in their ceremonies. Furthermore, a *cenote* or for that matter a *rejolladas* or an *aktun* is a part of



Figure 3.3 *Zuhuy ha'* drips into querns in *Rejollada* Thompson.

earthly space that every Maya individual is capable of transforming into two conceptually different places that coexist in the same temporal context, one sacred and the source of *zuhuy ha'* and the other a reservoir of life-sustaining *ha'*. Nevertheless, thirst is first in the heat of a Yucatecán afternoon. On one particular occasion, Maya workers did not hesitate to drink and offer me the sacred *zuhuy ha'* dripping from stone ledges into collection vessels. Although the dual

nature of water and the notion that, in some way, occupying privileged space near sacred *cenotes* or *aktuns* legitimized power for elites who dared to build their houses there is intriguing, I prefer to regard the practical nature of locational decisions more often as the principal motivational factor. In this paper more time is spent investigation material considerations of water rather than its symbolic nature.

In some instances, as in Valladolid, Yucatán, access to underground ponds is provided by partially collapsed surface stone. Local inhabitants call these features *cenotes*. *Cenotes* are collapsed dolines and solution shafts (Stringfield 1974) found throughout the Yucatán Peninsula. Many features of varying form are collectively named *cenote* by the inhabitants of Yucatán. The word *cenote* is a Spanish corruption of the Mayan word *ts'onot*. *Cenote* often refers to any cave, opening, or subterranean corridor that leads to water. Morley (1946) argued that where *cenotes* occur, they were the principle factor in determining the location of ancient centers of population. Furthermore, Morley (1946:12) compared *cenotes* to oases in a desert suggesting they were "...in short, the most important single factor governing the distribution of the ancient population in northern Yucatán". Prior to Morley's work, the relationship between settlement location and *cenotes* was noted

by others (de Landa 1978; Diaz del Castillo 1956; Holmes 1895a, 1897; Mercer 1975; Shattuck 1933; Stephens 1988). Shattuck (1933) and Roys (1939) included the location of *cenotes* in maps of portions of the peninsula.

The Roys (1939:6) typology is instructive and useful for this study. However, this paper does not attempt to redefine a typology of features. Instead it attempts to understand the spatial relationships between humans and their environment as indicated in settlement patterns and water management strategies. Roys' (1939) classification suits this purpose by providing a standard classification that is not as ambiguous as other typologies or the Mayan referents. Roys included three basic types of *cenotes* in the classification. Type 1 *cenotes* are the large vertical-walled sinks such as the *Cenote Xlacah* at Dzibilchaltún (Figure 3.4). This type represents the most advanced stage in an ongoing formation process. A Type 2 *cenote* in the classification consists of the distinctive bell-shaped chamber formed by the collapse of portions of the overlying strata of limestone, and a small opening directly above a subterranean pool of water (Figure 3.5). This type is similar to an *aktun* or cave but is lighted through a small natural or culturally constructed opening in its ceiling. These openings



Figure 3.4 Roys Type 1 Cenote, Xlakah at Dzibilchaltún.

were used by the ancient Maya to collect water. In modern times they are used in the same ways as in the past except steel and plastic buckets have replaced striated water jars as collection

At Mayapan, the Maya landowners construct *brocals* with winches, functionally converting several *cenotes* into wells. I use the presence of light, to distinguish whether or not features should be referred to as *cenotes* and *aktuns*.

Akalchen'o'ob is the *Mayan* referent used by the local vessels.



Figure 3.5 Roys Type 2 Cenote at Mayapan.

inhabitants of Piste, Yucatán, Mexico for dark caves with water. These dark caves are sources of *zuhuy ha'* and are considered to be sacred places. They are dolines or intermediate-stage *cenotes* with ceilings intact, or pre-*cenotes*. A Type 3 *cenote* gradually slopes from the surface on one side toward a pool of water beneath under ledge on another side.



Figure 3.6 Roys Type 3 Cenote, Kanchul at Aké.

This class of *cenote* was found at the bottom of several *rejolladas* visited during fieldwork (Figure 3.6).

More than 40 *cenotes* are documented at Mayapan in the southern part of the modern State of Yucatán. Most of the 32 *cenotes* investigated and mapped were Type 2 in Roys' classification. Dome shaped *cenote* chambers correspond to "type A" in the taxonomy of *Cenotes* advanced by Pearse, Creaser and

Hall (1936). The Maya refer to these features collectively as both wells, and *cenotes*.

The high incidence of *cenotes* at Mayapan is the result of processes caused by a complex system of underground streams and chambers that might derive from the effects of the impact of the meteor at Chicxulub, an event that took place around 64 million years ago. The occurrence of *cenotes* in the pattern known as the "ring of *cenotes*" appear to follow a trough running along the southern rim of the Chicxulub impact area.

Kinsland (personal communication 2002) suggested that structures, faults, and/or fractures within Tertiary and pre-Tertiary carbonates might have produced anomalous porosity zones that serve as conduits for ground water flow around the Chicxulub Impact crater until the water enters the Gulf of Mexico where the trough intersects the sea. The majority of *cenotes* in the ring occur near the trough of the impact crater. This might help to explain the pattern of groundwater discharge along the northwestern Yucatán coast (Kinsland, Hurtado and Pope 2000; Pope 1996). An examination of 1:250,000 scale geological maps of the Yucatán provided by INEGI revealed high frequencies of fractures that crisscross the surface in a crescent shape following the Chicxulub trough. It should be noted that many of the intersecting fractures appearing on

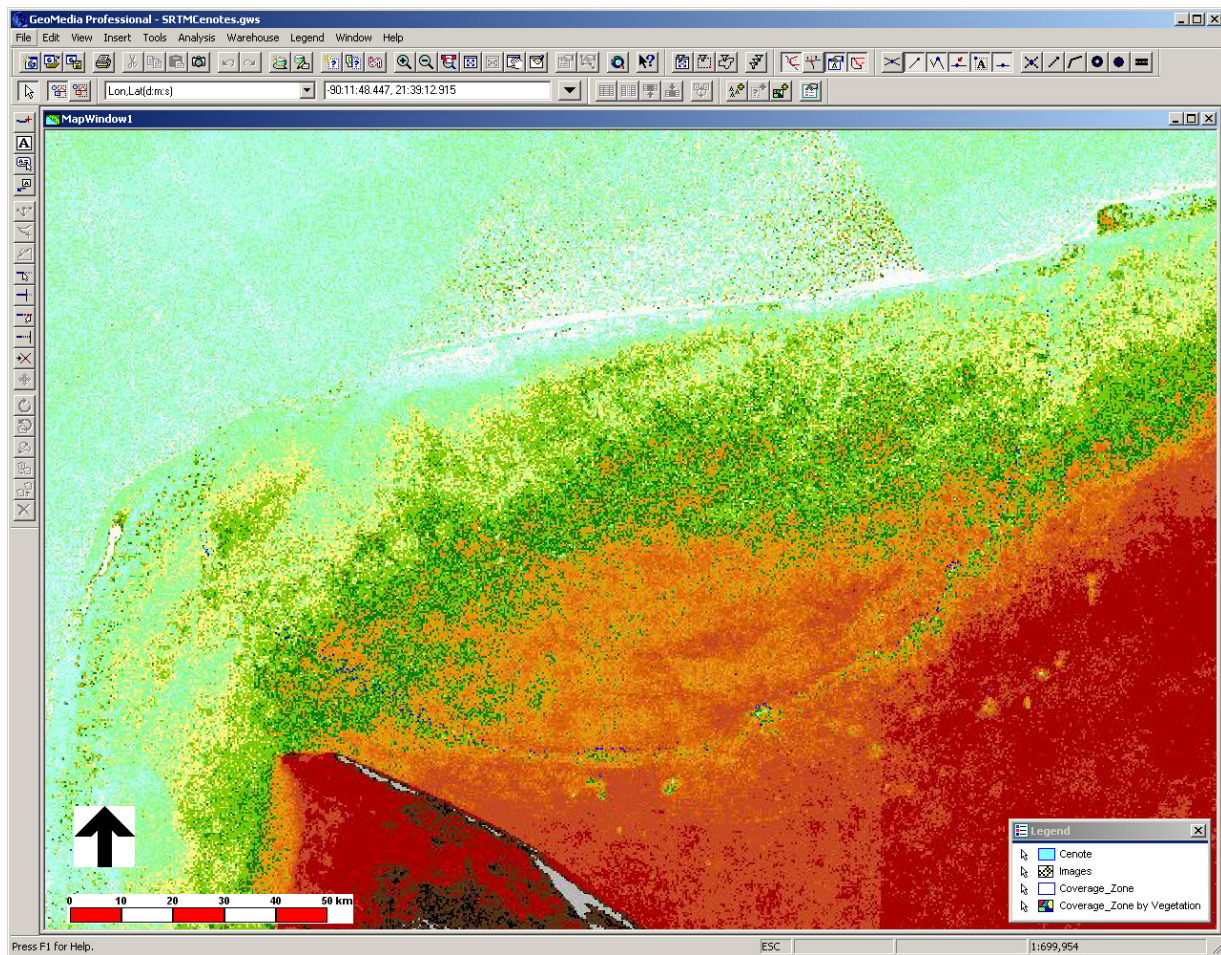


Figure 3.7 Ring of *Cenotes* as revealed in NASA SRTM C-band. Image courtesy of NASA.

INEGI maps are positioned in the same location as major cenotes suggesting they were noted by evidence of their effects, the cenotes. Fractures direct meteoric water in ways that aided in the formation of *cenotes* and sinks in the area. Figure 3.7 is a GIS screenshot of the ring of *cenotes* (blue dots) plotted over C-band Shuttle Radar Topography Mission data, SRTM. The data indicate relief. Light green indicates lower elevations. Red and black are highest elevations. Sea estavellas occur in high

frequencies on the western and eastern tip of the peninsula where the trough enters the Gulf of Mexico.

The ancient Maya were well adapted to their environment and possessed an awareness of limitations and possibilities of their human-environment relationship. As mentioned earlier, the Maya's practical environmental awareness is manifested in their language. The name of the town of Muna in *Mayan* means, "where the water begins." The ancient site and modern-day town of Muna is situated near the southern edge of the ring of *cenotes* and is located on the Sierrita de Ticul a ridge that follows a 135-kilometer long fault line that runs northwest to southeast across the peninsula.

A weathering process that includes solution of limestone, degradation of parent rock formations, erosion, and subsequent collapse of ceiling material causes subterranean cavities to evolve through time from irregularly shaped sub-surface hollows into covered dome-shaped chambers, and finally the well-known open vertical-walled circular features that plunge beneath the static water level Pearse, Creaser and Hall "type B" (1936) such as the Sacred *Cenote* at Chichén Itzá. During fieldwork, examples of features in each of these stages were observed.

At times, the modern day Maya distinguish between water taken from dark covered chambers, known as *ak'al ch'e'en'o'ob*

in *Mayan* (covered water-well or lagoon) and open, vertical walled *cenotes*, or *aktuns* in *Mayan*. In most instances, both men and women can collect water from *cenotes*, *rejolladas*, or *akalchens* for everyday use. In certain ceremonial contexts, water taken from these same features is *zuhuy ha'* and cannot be touched by women. During rituals, that might last for several days, men from the community collect the *zuhuy ha'* from one of several sacred places and incorporate it into ceremonies. During fieldwork, I was able to observe one such ceremony known as the Cha Chaac.

Solution shafts, referred to as natural wells, were encountered. Near the site of Coba in the modern day State of Quintana Roo, several were documented. The local inhabitants refer to these features as *aktun*. The *Mayan* word *ak* means turtle of the sweet water or stagnant water, and *tun* means stone. *Aktun* as a rule signifies a cave with water.

Contrastingly, the *aktun'o'ob* observed near Coba were small natural and irregular shafts penetrating the bedrock to depths of more than three to four meters. Local informants related that these features often reach the phreatic zone, or are filled with water during the rainy season. Similar but often much smaller features exist at the site of Aké in the modern State of Yucatán and other sites along the eastern

coastal plains. In these areas these features were called *ha'l tun'o'ob*, *Ha'l* means water and *tun* means stone. Roys (1939) referred to *haltunes* as water tanks.

In the eastern and western coastal plains and the Puúc area, *aguadas*, *ak'al'che'oob* in *Mayan* are lakes that were often modified to improve water retention, *sartenejas* (small puddles of water in slight depressions in the exposed limestone bedrock often filled for most of the rainy season) and *haltunes*, features similar in form to *sartenejas* but somewhat deeper and remaining filled with water throughout the year are found. Stephens (1988) noted the use of *sartenejas* during the rainy season by local inhabitants. South and southwest of the Sierrita de Ticul *aguadas*, caverns, chambers, and underground streams and lakes are common.

Chultunes and Wells

Chultunes, bell-shaped storage pits commonly believed to have functioned as underground cisterns, were found at most sites in all environmental districts within the region. Figure 3.8 shows the mount of an elaborate *chultun* found at Chichén Itzá. My interest is the spatial relationship between *chultunes* and other settlement units such as house platforms, palaces,



Figure 3.8 Elaborate *chultun* found at Chichén Itzá.

civic structures, and other water features. This study also investigates morphological and functional variation in different physical and social environments. Resolution of the ongoing debate concerning the function(s) of *chultunes*, however intriguing, is not a goal of this study. For this reason, the following discussion is limited to a few brief observations regarding major works and the thrust of investigative research on the topic over the past century.

A marked variability among the *chultunes* found throughout the region was observed. In some instances the variability appears to correlate with differences in the physical environment, for example depth of soil, thickness of cap rock, depth to and presence of a layer of *sascab*, marl used for mortar, or bedrock. Variation appears as differences in neck depth, diameter and design, morphological differences in storage chambers, the presence or absence of symbolic iconography or decorative elements, variation in preparation of the storage chamber to insure impermeability, and the presence of artificially constructed catchments. Some variation might be associated to socioeconomic status. A class of *chultunes* appears to be standardized.

The area of exception to the widespread distribution of *chultunes* is at sites located near the coastline where the phreatic was sufficiently near the surface to form natural springs, petens, sea estavellas, accessible in cenotes, or the Maya were able to excavate wells with stone tool technology. In Chapter Five, I discuss Dzibilchaltún. The site has the highest frequency of wells observed during fieldwork. The high incidence of wells seems to be correlated to both rainfall and



Figure 3.9 Ancient well in base of a *rejollada* at Chichén Itzá.

depth to aquifer. In areas where the phreatic approached or slightly exceeded the limits of the ancient Maya's traditional stone tool technology, populations excavated wells at the bases of *rejolladas*. Figure 3.9 depicts one of several wells investigated in *rejollada* contexts.

Diego deLanda (1978:96) authored the earliest historical document to mention *chultunes*. He noted an adaptive strategy used by the Maya living near the "sierra," the Puúc Hills, "...

needing to have their wells very deep, are accustomed to gather the rainwater for their homes in that season, in great cavities in the rocks; because very heavy rains come then, with much thunder and lightening at times." Diego deLanda does not refer to these features *chultunes*, but was clearly describing them.

The word *chultun* used by the Spanish, is derived from the Mayan word *chulub tun* meaning either a chamber in rock for storage of corn or to collect rainwater (Barrera-Vasquez 2001). This semantic duality alludes to the ongoing debate among scholars of the ancient Maya regarding the nature and function of *chultunes*. Wittfogel (1957:185) cited Stephens (1843) regarding the *chultunes* at Uxmal as representing "immense reservoirs for supplying the city with water."

It would appear that Wittfogel was clear as to the true function of *chultunes*. Others were and are not so convinced. Dennis Puleston argued that *chultunes* were storage pits for ramon nuts (*Brosimum alicastrum*) (Puleston 1965, 1968, 1971, 1978). Experiments using ramon nuts and maize failed to support the storage model. Over the years *chultunes* have been treated as multi-functional repositories to include water-food storage of jute snails, the genus *Pachychilus*, in a *chultun* at Xunantunich (Keller 1995), sweat houses (Puleston 1971; Ricketson and Ricketson 1937), and burial tombs or chambers

(Thompson 1897b). Thus far, a single indisputable function of *chultunes* eludes researchers.

There are several instances where *chultunes* are found in contexts that do not suggest a water storage function. *Chultunes* constructed by excavating through solid cap rock into an underlying layer of permeable *sascab* could not hold water for long periods of time. An argument might be made that this particular kind of *chultunes*, often situated on plazas, functioned both as a resource for *sascab* during construction of buildings, a storm drain to prevent flooding of plazas during the rainy season, and a storage tank for consumable water while the captured rainwater slowly percolated out through the porous *sascab*. Furthermore, sites like Aké are found that have no *chultunes* or other identifiable water storage features except one *aguada* most-likely Colonial Period, and a few widely dispersed (several kilometers apart) *cenotes*. Interestingly, the site has several *sascaberas*, quarries used by the ancient Maya for the extraction of *sascab* (Winemiller 1996, 1997). An argument could be made that *chultunes* are cumulative features that came about during the extraction of *sascab* for construction. Once excavated, they could have been placed into service for a variety of purposes. This is an example of secondary use of a feature by the Maya.

The Maya today are practical people using and reusing tools and structures probably like they did in the past. There is no reason to expect that they would not have assigned multiple functions to features over the course of their useful life. If the secondary function of *chultunes* was water storage and they were primarily excavated to extract *sascab* the absence of these features at sites like Aké should correlate to the presence of *sascaberas* near architectural features, and as Kurjack (2003) noted, should precede formal masonry structures.

At Coba and Cumtun *chultunes* were found within 100 meters of cenotes or lakes. The presence of *chultunes* in places where other easily accessible water features exist suggest multi-functionality and implies that ownership of *chultunes*, in certain instances, might have been a matter of convenience or economics. Moreover, a few privileged individuals might have been the only inhabitants who could afford to have water storage chambers constructed. Many of the *chultunes* observed at Coba were situated adjacent to elite, vaulted, architecture. In spite of the debate, most archaeologists consider *chultunes* as primarily receptacles for rainwater and evidence of an adaptive strategy employed by the ancient Maya in areas where few or no natural sources of water were readily available.

Over nearly two centuries of exploration and scholarly research in Yucatán, many archaeologists and geographers commented on the presence and function of *chultunes* in publications and site reports. To cite all of these works is beyond the scope of this paper. Instead, I will comment on a few major works. Thompson (1897b) published the first monograph to specifically describe the variety of *chultunes* at the archaeological site of Labna. Thompson described the form and function of thirty-four *chultunes* at the site. Knowing that *chultunes* were vital to the survival of the ancient Maya in a region where water was most difficult to find, Thompson was intrigued by the fact that the ancient Maya used many of these as tombs to bury their dead (1897b). This seems to be the case in the Belize Valley as well (Gray 2001), and (Chase and Chase 1987). If water storage represents the principal and essential function of *chultunes*, why would the ancient Maya convert such a vital resource to a burial pit? The answer might be that these particular *chultunes* were no longer functional. Zapata Peraza (1989) completed an intensive study of *chultunes* at the site of Chichén Itzá and in the Puúc region of the Yucatán peninsula. Her study, like Thompson addressed form and variation. Both studies highlight the wide variety of *chultunes* found throughout the region.

Aguadas and Canals

Aguadas are shallow natural depressions that were modified by the ancient Maya to enhance water retention or extend their depth. *Aguadas* or canals were observed at several sites throughout the region, including Aké, Becan, Dzibanché, Kohunlich, Coba, Calakmul, Edzná and Uxmal (Figure 3.10). A few sites, Calakmul and Edzná have extensive canal systems that link networks of *aguadas*. At least one *aguada* and possibly more at Dzibanché appear to be tied to the Rio Escondido that flows nearby and through the modern town of Morocoy. At Kohunlich, a large rectangular feature, the Plaza Hundida, had a plastered floor, carved stone retention walls, and stairways. Two drains, located on the northern rim, channel water from the plaza to an *aguada*, *Aguada 1*, 200 meters northeast and 25 meters below. It is possible that Plaza Hundida was intentionally designed to be a reservoir for the site. A large natural gorge known as the *cañada*, actually a canal, moves water around the site core and into the *Aguada 1*. As discussed above, several historical accounts revealed *chultunes*-like features known as *buk'tes* that extended the depth of *aguadas* beneath their clay linings.

The site of Becan contains evidence of *aguadas* and an enigmatic canal. A large dry moat-like ditch, varying in depth between two and four meters and from three to twenty-five



Figure 3.10 *Aguada* at Uxmal

meters in width, surrounds the entire site core of Becan (Figure 3.11). Seven causeways, *sacbe'o'ob* in *Mayan* (meaning white road) cross the canal and enter the site from different directions. A large *bajo* is located north northeast of the site. Ruppert and Denison (1943) speculated that the *bajo* was originally an *aguada* or lake that drained into the defensive moat but had filled with silt over the centuries since the site was abandoned. Thompson (1954) proposed that the "moat" was



Figure 3.11 Moat at Becan, view looking toward the south.

constructed possibly for defensive purposes but not completed in Terminal Classic Period by a group of elites. Pollock (1965) described the feature as a large borrow pit excavated to provide fill for architecture and platforms in the site core. Webster (1976a) and others (Potter 1977) argued that this feature was defensive in nature. As yet the debate regarding the function of the canal is unresolved. The physical evidence suggests the canal served to drain the site core. Whether or

not drainage was a principal or secondary function is a matter of debate. A comparatively large *aguada* within the area enclosed by the canal.

Soils

The characteristic red soils of the Yucatán peninsula accumulate in pockets interspersed between ubiquitous bedrock outcrops. Most of the soils of northern Yucatán are dominated by kaolinite. Kaolinitic soils occur in fairly well drained areas experiencing moderate rainfall. In pockets where drainage is poor, such as large basins, soils contain high levels of montmorillonite. Both soil types are red in color due to the presence of iron. In some areas the soil has turned dark red through oxidation of organic materials. The oxidation process occurs more rapidly in areas where the Maya have burned off fields for swidden agriculture. The resultant exposure accelerates the oxidation process.

Lenses of attapulgite or palygorskite-sepiolite and kaolinite-montmorillonite clays occur in the Puuc region, Sacalum in northwestern Yucatán and several areas near Ticul. These clays were used by the ancient Maya for ceramics and are ingested on a limited basis by the ancient Maya and modern day inhabitants for medicinal purposes (Folan 1969; Roys 1931).

Maya folk terms for soils include *sahcab* or *sascab* (a soft weathered limestone marl), *ka'kab* (a red loamy soil), *ek lum* (a rich black soil), and *tzekel* (a stony soil). Soil orders used in the United States that apply to Yucatán include Entisols, Histosols, Mollisols, Oxisols, Spodosols, Ultisols, and Vertisols. Like the Mayan terms for various types of water features, folk classifications for soils do not conform to rigid standards and are somewhat ambiguous. In Yucatán, Entisols (recent soils resulting from the erosion of limestone, referred to as *sascab* by the Maya), Mollisols (soils having a dark strong surface horizon rich in calcium and montmorillonite), and Vertisols (rich montmorillonitic soils developing from limestone and marl) are most common. Where Histosols (organic soils of any thickness) are found they overly limestone and are relatively thin, 10 to 20 centimeters thick.

Climate

In the tropics and sub-tropics, altitude is often a significant variable in determining regional variation in climate and ecosystems. For all intents and purposes, the Maya classification of land based on elevation is modeled on the same principle as the relationship between climates and vegetation advanced by Alexander von Humboldt, known as

altitudinal zonation. In general, the Maya classify land into three broad categories based on elevation. Lands below 1000 meters in elevation are known as *tierra caliente* (hot land), from 2000 to 3000 meters as *tierra templada* (moderate land), and above 3000 meters as *tierra fria* (cold land) (Hammond 1988).

The study area falls completely within the *tierra caliente* zone where mean annual temperatures range between 25 degrees and 30 degrees Celsius. The rainfall in Yucatán is controlled in part by both the Gulf of Mexico and the Caribbean Sea. The region under study experiences a rainy season that lasts from May through November and a dry season lasting from December through April. In some areas the dry season produces desert-like conditions. The Yucatán also experiences frequent tropical storms. Ancient locational decisions and rainfall were related.

Wilson (1980) reported mean annual rainfall ranging from 2500 millimeters in the southern study area to 500 millimeters in the extreme northwestern coast of the peninsula. Figure 3.12 shows rainfall variation across the peninsula. Under the Köppen climate classification system, the majority of the study area is designated as Tropical Savanna (Aw) or Tropical Wet-and-Dry, with the driest month rainfall totaling less than 60 millimeters. The northwestern coast of Yucatán is Semi-Arid

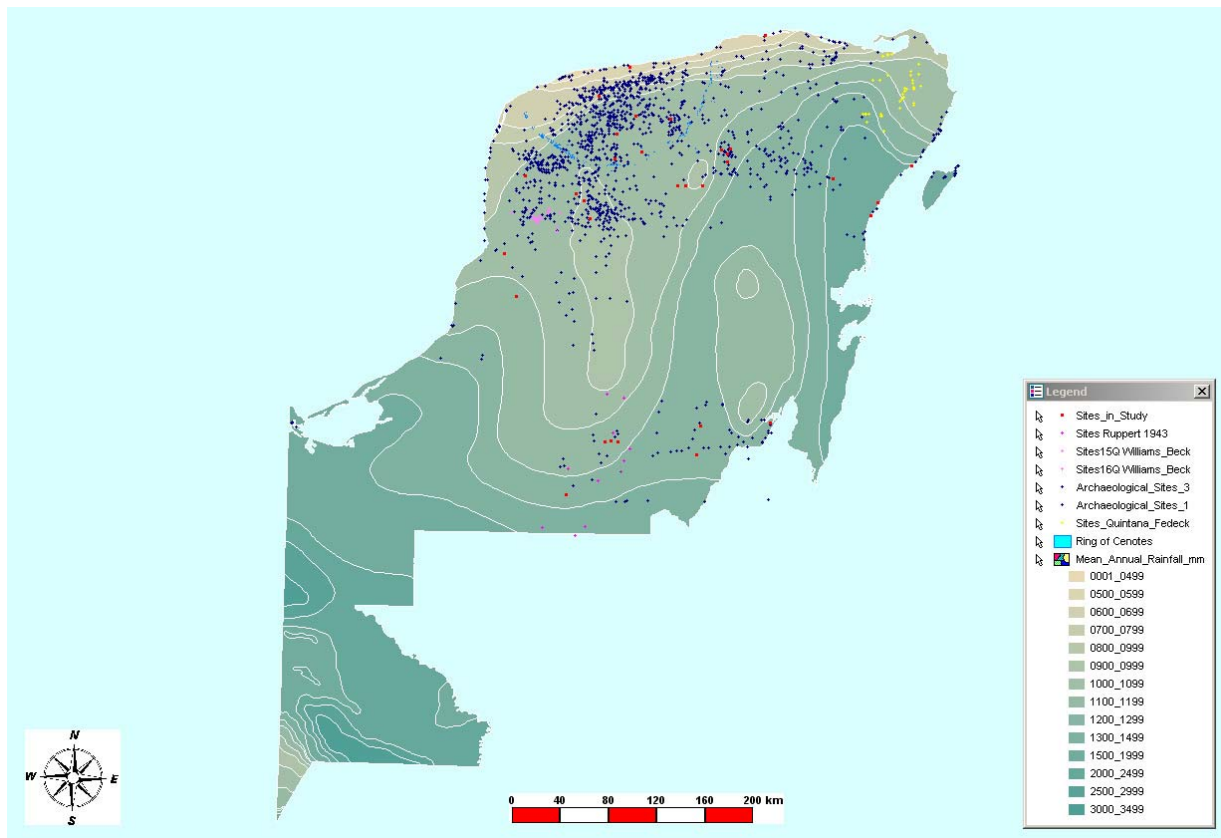


Figure 3.12 Mean annual rainfall and archaeological sites.

type (Bs), having less than 500 millimeters of annual rainfall with high evaporation levels. Dry zones were occupied by more dispersed populations. A more thorough climatic classification was used to model the Yucatán environment in a GIS.

Vegetation

Vegetation coverage in much of the Yucatán Peninsula belongs to the dry evergreen formation (Beard 1955; West 1964). Extended drought combined with cultural factors such as

expansion of areas under cultivation and deforestation would have placed increased pressure on the environment of Yucatán. Furthermore, the floral population likely shifted toward more xerophilous varieties within the series. Today, vegetation coverage throughout the region is influenced by human activity. Within the zone of dry-evergreen-formation the general vegetation coverage makes a transition from "dry rain forest" to "evergreen bush land" as you move northward. Much of the northern area is dominated by low scrub forests interspersed with open patches of palmetto and mixed grasses.

Climate more than soil type appears to be a principal determining factor for the location of dry evergreen formations (Beard 1955). Along the coasts, Beard's (1955) *swamp* series predominates in estuary settings. A transition between the dry-evergreen-formation and a tropical-rainforest-formation begins near Campeche on the southwestern coast of Yucatán and extends northeastward to the eastern coast north of Cozumel Island. Tropical forests have canopies reaching approximately 60 meters above the forest floor. The rainforest includes mahogany, breadnut (ramon), rubber, sapodilla, palms, and the Ceiba tree. Portions of the southwestern study area near the Tabasco Plain include drainage basins containing some components of the seasonal-swamp-series.

Swidden agriculture, the subsistence strategy practiced by many of the modern-day Maya, requires large amounts of land. Ash created during fire-clearing fertilizes the barren soil. The Maya refer to their plots as *milpas*. *Milpas* are planted for no more than three successive years, then are left to fallow for approximately ten years. This slash-and-burn agriculture has impacted and continues to impact native vegetation coverage in Yucatán.

Paleoclimate and Water

Although there is evidence for climatic change throughout the history of Maya occupation of the Yucatán, the introduction of cattle and commercial henequen operations has most likely had the highest impact on vegetal coverage in modern times. The situation is once again changing. With significant reductions in henequen production, once cultivated henequen fields are returning to a native-like state. However in general, there are few areas in Yucatán where native-state vegetation coverage can be found today. The site of Calakmul is located in one.

Consideration must be given to potential variation between modern-day climate and paleoclimate across the Yucatán Peninsula. Traditionally, researchers believed that there was little climatic variation between modern times and the period

of classic Maya civilization in Yucatán (Turner II 1978a). Recent data suggest that in some ways the physical environment of Yucatán today may be somewhat different than in the past but climate has not changed radically. Historical documents from the period of Spanish conquest provide evidence that the climate in México and Yucatán during the 16th Century closely resembled modern trends (de Landa 1978; del Castillo 1521).

Pollen samples in cores taken from lake bottoms in the region indicate that a severe drought may have occurred from approximately A.D. 250 until 650 (Dahlin 1983; Deevey, Brenner and Binford 1983). Other research indicates that extant environments may not be indicative of conditions in the past (Dahlin 1983; Hodell, Curtis and Brenner 1995; Leyden 1987). Evidence from south coastal Belize suggests that a rise in sea level occurred after A.D. 900 thereby reducing the exposed landmass and altering vegetation patterns (McKillop 1989, 1995, 1996, 2002). In addition to altering the visible landscape, a rise in sea level of one to two meters would have impacted water quality in areas where the Maya excavated wells. Many of these productive features might have been rendered ineffective through saltwater intrusion (Scarborough 1993b).

Rises in sea level of this magnitude may be due to a global scale rise in mean temperatures causing reductions in

glacial ice and increases in the amount of rainwater flowing back to oceans. Some researchers argue that reduced pollen levels in lake-bottom core samples reflect deforestation (prompted by population growth, agricultural expansion, and harvesting timber to fire limestone kilns for the production of plaster) that occurred from roughly 300 B.C. until A.D. 900. The numerous lines of evidence presented in this paper clearly suggest an extended period of drought and lower than average rainfall might have precipitated changes in vegetal coverage and in turn reduced the likelihood that some groups could make a living in portions of the Yucatán Peninsula.

Changes in worldwide climate can be tracked by analysis of the ratio between two oxygen isotopes, ^{16}O and ^{18}O in seawater. Both ^{16}O and ^{18}O are present in seawater. Since ^{16}O is lighter than ^{18}O water containing it evaporates at a faster rate than water containing ^{18}O . During warmer climatic conditions, the evaporated ^{16}O returns to the oceans by way of drainage systems. If global temperatures are generally cooler, the ^{16}O is returned to the surface in snow at northern latitudes and high elevations and remains locked in ice sheets until a cycle of warm climate returns. The result of this climatic variation is varied $^{16}\text{O} / ^{18}\text{O}$ ratios in seawater through time. Plankton-like marine organisms, *Foraminifera*, incorporate ^{16}O and ^{18}O into

their skeletons reflecting the ratio of these elements in seawater during their lifetime. These ratios are measured using a mass spectrometer (Fagan 2001). Stratigraphic columns of sub oceanic deposits dated by assuming constant rates of deposition and known shifts in the earth's magnetic field are used to correlate ^{16}O / ^{18}O ratios to periods of global climatic variation.

Hodell, Curtis, and Brenner (1995) provided compelling data for a shift in climate in Yucatán. The data suggest that an extended period of dry climate prevailed in the region from A.D. 250 to 1050. They collected sediment cores from Lake Punta Laguna near the site of Cobá in the modern state of Quintana Roo. The cores provided a sedimentary record spanning 3,500 years. A procedure similar to ^{16}O / ^{18}O ratio analysis of sea-bottom was used to measure levels of ^{18}O in the shells of ostracods (freshwater crustaceans). The relative abundance of ^{18}O in sediments correlates to evaporation and precipitation. A low concentration of ^{18}O in sediments indicates normal or wet conditions. High concentrations of the oxygen isotope indicate drought. By analyses of the varying levels of ^{18}O in core samples from Lake Punta Laguna, Curtis, Hodell, and Brenner were able to reconstruct the paleoclimate of northern Yucatán for a 3,500-year period.

The Curtis, Hodell, and Brenner data indicate that during the Preclassic Period ca. 1800 B.C. to A.D. 250 the climate was much like today (wet) as evidenced by low concentrations of ^{18}O . After A.D. 250, the data indicate a shift from wet to drier conditions with a peak around A.D. 585 to 600. This event represented a major drought. Archaeological evidence from parts of Yucatán suggests that Maya society was undergoing dramatic changes. The period of drier conditions correlates with an event in Maya history known as the "Great Hiatus," a period traditionally marking the boundary between the Early Classic and Late Classic Periods (A.D. 600 to 800) when the construction and erection of *stelae* (monuments depicting rulers, their divine ancestry, and major events in local political history) cease in central Yucatán. The cores from Lake Punta Laguna also indicate a second more severe drought occurred during the Terminal Classic and Early Post Classic Periods, ca. A. D. 800 to 1050. The data suggest this period was perhaps the driest of the 3,500-year period.

McKillop's (1995, 2002) data document a rise in sea level of one to two meters at six archaeological sites situated off the Belizean coast. Other inundated sites were reported by (Freidel and Scarborough 1982) at Cerros, (Dahlin et al. 1998; Dunn 1990; Dunn and Mazzullo 1993) at Punta Canbalam, Yucatan,

Mexico and Marco Gonzalez, Belize (McKillop 2002) respectively. The sequences of occupations and subsequent rise in sea level noted by McKillop correspond to the rise in sea level discussed earlier.

Changing sea level combined with periods of lower rainfall would have affected perched water tables and might have caused saltwater intrusion into wells and springs near the coast, and *cenotes* and *aktuns* further inland. The data suggests that from the Middle Post Classic to the present, the climate has remained fairly stable. Fluctuations in rainfall would likely have caused more water stress near the coast where sea estavellas, springs, and shallow wells provided water for consumption. Along the coast, fresh water is one to two meters beneath the surface in many areas. At Dzibilchaltún, situated around 22 kilometers from the coast in the modern state of Yucatán, the water table is three meters below the surface, easily accessible by shallow well. A reduction of one to two meters in sea level combined with the possibility of reduced groundwater flow from the interior toward the coast might have been catastrophic for inhabitants of lower elevations. Further inland, where the phreatic occurs at considerably greater depths beneath the surface, lowered sea levels and rainfall amounts might have had less impact since many adaptive

strategies in the interior involved capture of rainwater in *chultunes* or *aguadas* rather than excavating wells or gathering water from natural features such as caves or *cenotes*. Furthermore, inhabitants collecting water from caves would have had to explore caverns to greater depths.

Discharge data from the Rio Candelaria were used to reveal a fundamental relationship between temperature and rainfall that can be used to reconstruct paleoenvironments. Gunn, Folan and Robichaux (1995) analyzed discharge data for the Rio Candelaria for a period from 1958 to 1984 and concluded that the most significant factor affecting rainfall in the region was the Global Energy Balance, average annual temperature of the atmosphere. Changes in global temperature, recorded in polar ice can be used to model significant changes in rainfall patterns that took place across the Yucatán Peninsula in ancient times. The evidence suggests that severely cold temperatures during the Ninth Century might have resulted in reduced precipitation levels.

Data reported by Gill (2000) support the notion of a period of drier climates and moderate droughts. Gill suggested that the northeast to southwestern movement of the North Atlantic high-pressure area influences precipitation levels in the Yucatán region. The mean extent of normal seasonal movement

of the high-pressure area is affected by changes in Arctic temperature. Lower mean arctic temperatures cause the mean cyclical position of the North Atlantic High to extend further south and west. The further south the high-pressure zone is located, the less likely convection, associated cumulus clouds, and rainfall. Evidence to date suggest that over the past two thousand years significant changes in temperature took place, resulting in localized or in some cases regional episodes of moderate to severe drought. However, none of the evidence argues for variation significant enough to conclude that climate for the entire span of Maya high civilization across the Yucatán Peninsula was sufficiently different than that documented in historical times.

Ceramic data collected during fieldwork and settlement patterns clearly demonstrate that the ancient Maya were utilizing the various natural and constructed water features documented during this study as sources for water. Moreover the ancient Maya practiced the same subsistence strategies in the past as they do today. This strongly suggests that the climate in the Yucatán, although somewhat drier for periods of time, was not sufficiently unlike that of today to cause a major shift in lifeways from past to present. Thus, observations of extant sources of water or evidence of its presence in the past

are likely to accurately represent the range of potential water resources available to the ancient Maya.

CHAPTER 4

CERAMICS AND ARTIFACTS

Ceramics

Ceramic and artifact data for this paper were primarily collected from surface areas adjacent to water features, nearby associated architecture, surfaces and the perimeter of platforms and terraces rather than excavation units. Surface collection as a practical tool to make inferences about ancient settlement organization and activity areas has been demonstrated, especially where limited use-life artifacts such as utilitarian ceramics or lithics were regularly deposited as refuse in considerable quantities (Connolly and Sullivan II 1998; Downum and Brown 1998; McKillop 1989; McKillop, Winemiller and Jones 2000; Ochoa Rodriguez 1995, 1999; Smyth 1998; Sullivan 1998; Winemiller 1996, 1997, 2000a, b). A fraction of the ceramics collected during field survey was recovered from excavations at Dzibilchaltún, Uxmal, and Sayil.

This is not the first study to investigate the geography of ceramics, see (Ochoa Rodriguez 1999), but it is the first to integrate geographic coordinates of surface features and artifact distributions recorded with a Global Positioning System data collector into a GIS for analysis of associations

between various categories of archaeological evidence at different scales of settlement. The precise geographic location of each artifact collected during fieldwork is known. This method, whereby spatial and non-spatial data were recorded in relational tables, permitted me to employ the GIS to query specific artifact distributions for relationships with other types of artifacts, features, or settlement units at various scales, and accurately distinguish a site / situation profile for each settlement. Moreover this method permitted incorporation of data collected by other researchers into spatial analyses as well.

Analysis of ceramic and non-ceramic materials was a collaborative effort with Virginia Ochoa Winemiller, and José Manuel Ochoa Rodríguez. The ceramic collection is temporarily housed at the project office in Merida, Yucatán, Mexico and will be used to assemble two type collections for use by archaeologists and geographers. A discussion of the ceramic evidence recovered during survey and summary by group follows.

Type-Variety

A total of 3,322 ceramic sherds were classified see Appendix C. Twenty-four pieces were not identifiable due to their small size or eroded surfaces. Using the Type-Variety system implemented by Smith, Willey and Gifford (1960), sherds

were classified at the level of type, group, and complex. The analysis revealed 63 ceramic groups including 140 ceramic types together with unspecified groups and unidentified sherds.

Ceramic complex and type were considered to develop approximate date ranges for ancient human usage of water features surveyed in the field. Thus, a specific type is discussed only to the extent it might aid in attempts to construct a temporal sequence for a particular feature, group of features, and/or settlement units at a specific site. For this purpose, I considered Cehpech, Sotuta, and Hocaba as completely overlapping Complexes that correspond to the Terminal Classic and Early Postclassic Periods (c.a. A.D. 850 to 1200) in most sites (Adams 1977; Ball 1977, 1985; Chase and Chase 1985; Chase and Rice 1985; Ochoa Rodriguez 2003; Ochoa Rodriguez 1999). My ending date, A.D. 1200, is somewhat earlier than Ball (1977, 1985) suggested. This period roughly corresponds to the Vista Alegre horizon in the East Coast of the peninsula and places the beginning of the Postclassic Period between A.D. 1200 and 1300 with the appearance of Tases Complex ceramics.

Ceramic Form

For this paper, I found it informative to study the percentage of vessel shapes by total collection, physiographic

district, site, water-feature, and associated settlement unit. Additionally, I compared frequencies in this collection to those reported by Ochoa Rodriguez (1995) for a domestic group at the site of Dzibilchaltún, Yucatán, Mexico to determine if significant variations in frequency by shape could be attributed to functional differences in locale.

During fieldwork, pottery was collected from twelve contexts defined as hydrological or water-features. These include *aguadas*, *akalchens*, *aktuns* or caves, *cañadas* or canals, *cenotes*, *chultunes*, cisterns, *haltunes*, *pozos* or wells, *rejolladas*, *sartenejas* and *sascaberas*. Activity areas, altars, groups, household spaces, mounds, paths, platforms, causeways, structures, terraces, and towers were considered non water-feature contexts. An activity area was discovered during survey along the shore of Lake Coba. The artifact distribution included several worn ceramic sherds, a cluster of obsidian flakes and several broken obsidian blades. Considering the context, this distribution might represent an area where inhabitants were processing fish harvested from the lake and will be discussed further in the site review.

Of the 3346 ceramic sherds collected, 1,763 pieces, 52.69 percent of the total collection, were recovered from hydrological or water-feature contexts. The remaining 1,583

sherds, 47.31 percent, were found on or adjacent to non-water features such as the mounded-remains of platforms or structures, and residential areas. Pottery collected from five types of water-features, *aguadas*, *cenotes*, *chultunes*, *rejolladas*, and wells accounts for 94.27 percent of all pottery specimens recovered from water-feature contexts. Two types of water-features, *chultunes* and wells, represent 59.27 percent of the total collection recovered from this context. Platforms and structures produced 47.31 percent of the collection from non-hydrological contexts.

Five shapes, basins, flat-base bowls, grater tripod bowls, round ringstand-base bowls, and jars account for 96.35 percent of the entire collection consisting of 26 different forms. Four vessel shapes, basins, flat-base bowls, round ringstand-base bowls, and jars account for 95.92 percent of pottery recovered in hydrological contexts. Of this total, jars account for 70.96 percent. Five shapes, basins, flat-base bowls, grater tripod bowls, round ringstand-base bowls, and jars account for 96.46 percent of the collection taken from non water-feature contexts. Five vessel shapes, cups, flat-base dish-bowls, inverted Z-lip jars, medial angle bowls, and soup bowls were found exclusively in water-feature contexts. Five shapes, cylindrical vases, tripod jars, miniature round-base bowls,

miniature jars (*ollitas*), and pear-shaped vases were collected in other contexts, none classified as water-features. Exclusive vessel shapes account for 1.46 percent of the water-feature collection and 0.32 percent of pottery collected in non-hydrological contexts.

Jars dominated the collection from water features. Three of seven vessel shapes, basins (10.98 percent), flat-base bowls (19.08 percent) and jars (56.65 percent) total 86.71 percent of pottery collected in *aguadas*. Two shapes out of three, bowls grater-tripod, and jars represent 96.42 percent of all pottery found in *akalchens*. Two shapes, flat-base bowls and jars dominate collections from canals, caves, *cenotes*, and wells totaling 77.28, 91.67, 93.33, and 85.91 percent of each collection by feature respectively. In one context, cisterns, flat-base bowls and jars were the only two shapes recovered.

Diversity in collections, measured by the number of different shapes represented in collections from each context, varied considerably, ranging from two shapes from cisterns to fifteen from structures. For water features, the collection from *chultunes* was most diverse, containing twelve different forms.

In general, non water-feature contexts measured higher amounts of diversity in form. In collections from causeways and

towers, flat-base bowls and jars accounted for 93.85 percent and 92.68 percent respectively. Three vessel shapes, basins, flat-base bowls, and jars totaled 94.42 percent and 90.87 percent respectively of collections from solitary platforms and unclassified structures. In small architectural groups, flat-base bowls, round ring-stand base bowls, and jars accounted for 93.33 percent of the collection.

Ceramics from this collection were used to develop a site chronology of water feature usage (Figure 4.1). The chronology established from project collections was compared to known dates to determine whether or not water feature use reflected known dates for sites in the study.

Functional Space and Vessel Shape

How does the ceramic evidence inform us about the ancient Maya and their use of water resources? Predictably, my collection suggests that certain vessel shapes are linked to particular functional spaces. When considering vessel form, collections from water contexts were only slightly less diverse than those taken from associated architectural contexts. A higher incidence of non-utilitarian ceramics exists in non-water feature contexts. If the assumption is that a more-limited set of activities, for example gathering water only, took place at water features as compared to within residential spaces, less

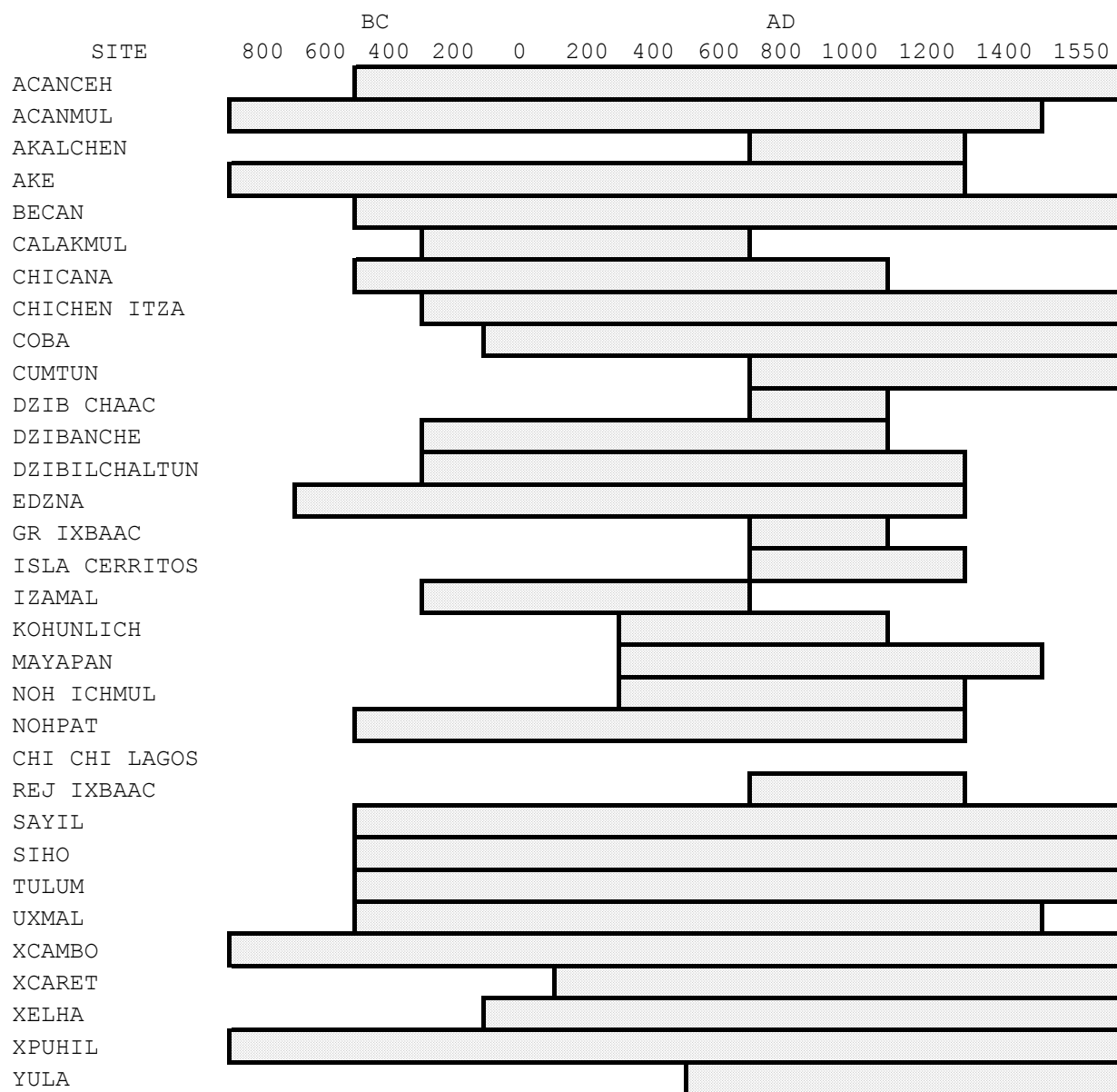


Figure 4.1 Site chronology based on ceramic collections.

diversity should exist in pottery collections from water features. The slight variation in pottery from both contexts as noted above suggests a range of tasks were accomplished at or near water features.

Ethnographic evidence can be found to support conclusions drawn from archaeological evidence. In Chan Kom and Eastern Quintana Roo, Redfield and Villa Rojas suggested that all agricultural labor is men's work and drawing water from *cenotes* and wells is woman's work Redfield and Villa Rojas (1934, Villa Rojas (1978). "The rim of the *cenote* is a woman's precinct; this is the principal place where women meet throughout the ordinary day, filled with household tasks that otherwise keep each to her house..." (Redfield and Villa Rojas 1934). Water feature tasks included collecting water, cleaning, food preparation, and other chores that required water such as bathing. In Oxkutzcab, Hanks (1990) observed that management of domestic water, including gathering, storing, heating, cooking and washing with it as well as watering gardens are specifically female tasks. The Maya kitchen like women was private or wet, a place where water was stored (Hanks 1990). In some instances, micro-scale settlement patterns at Coba, Chichén Itzá, Cumtun, and Dzibilchaltún define household unit or group as a water feature, such as an *aguadadita*, *chultun*, or well; a sub-assemblage of artifacts consisting of a number of vessel shapes, *metates*, *manos*, and other lithic tools such as obsidian blades, and a house or group of house structures. Jars dominate collections from all contexts. If frequency suggests

versatility, this form was the most functional and versatile vessel shape. It was used to collect, capture, store, and transport water as well as other substances. The second most frequent shape in all contexts is flat-base bowls. These were most likely used in food preparation and service.

The spatial data suggest a tripartite relationship between a particular assemblage consisting of utilitarian ceramics and non-ceramic artifacts, water-features, and domestic space. In addition to the presence of utilitarian ceramics and other artifact classes in these contexts, a majority of the *chultunes* and wells observed during survey were situated near or adjacent to domestic or habitation structures or platforms as functional components of Maya residential space. In certain contexts, the relationship applies to elite residential structures and palaces as well. However, elites might not have been as concerned with proximity of water storage or extraction features as non-elite residents. Elite residents would have had sufficient resources to compensate others for tending to menial chores. Thus, the definition of elite residential space might not necessitate finding an adjacent water source.

Kowalski (2003) cited the absence of a *chultun* in the courtyard of the Nunnery Quadrangle at Uxmal as evidence for a non-domestic, administrative role for the structure, often

described as a palace having elite-residential functions. Several lines of evidence argue against this assumption. Archaeological excavations might have destroyed ancient *chultunes*. One need only search the literature to find examples of lost features. Detailed descriptions, sketches and maps of ancient Maya sites document countless archaeological features destroyed by investigation and restoration efforts. During a visit to Uxmal, Maler (1997) documented a *chultun* situated on the platform supporting the Governor's Palace and House of the Turtles (Figure 4.2). No evidence of this *chultun* can be found today. Though early maps of the Nunnery Quadrangle fail to reveal them, *chultunes* might have existed inside the courtyard. The presence of a water management feature was most likely not required for all residential space. During survey, I documented six *chultunes*, the most distant was 185 meters from the central courtyard, and the nearest within 70 meters adjacent to the northwest corner of the structure. Another *chultun* lies to the south just beyond the same wall at a distance of 85 meters. Clearly, the aforementioned *chultunes* could have served elites residing in structures such as the Nunnery Quadrangle.

Relationships such as those between *chultunes* and the Nunnery Quadrangle were observed elsewhere in the region



Figure 4.2 Maler's sketch of Governor's *chultun* (1977:233).

linking *aguadas*, wells, and *chultunes* to elite residential structures. Moreover, Carr and Hazard (1961) documented 197 *chultunes* within the central nine square kilometers of Tikal and Puleston (1971) reported over 220 *chultunes*, none located in the central ceremonial precinct. At Becan, Thomas Jr. (1981) reported 15 *chultunes*. Again, none of the *chultunes* at Becan occur in within the central precinct. There are no documented *chultunes* within the central precinct of Chichén Itzá. Does this evidence validate early ideas about vacant ceremonial sites and confirm that there were no occupants, elite or otherwise, residing in the central precinct at Becan, Chichén Itzá, or Tikal? Almost certainly not, but the data suggest that

elites most likely had water brought to their palaces by others.

Artifacts

During survey samples of bone, reused ceramics, charcoal, chert cores, flakes and points, ground-stone choppers, manos and hammerstones, iron tools, lead shot, metal coins, obsidian flakes and blades, worked and un-worked shell, plaster and soil were collected from water-related and non-hydrological contexts. Artifacts are listed below by classification, quantity collected, catalog number, description of the artifact, possible function of each, context, and lot distribution indexed by site. The material evidence supports the tripartite pattern noted earlier in this paper. For example, *metates* and *manos* were found adjacent to or near *chultunes* or wells. In addition to portable materials collected for laboratory analysis, features such as *metates* and carved-stone decorative elements were sketched, measured, photographed and recorded in journals and data collection forms during field survey. All artifacts were inked, catalogued, and photographed in the lab. Like individual ceramics sherds, the geographic coordinates of artifact distributions were recorded with the GPS data collector and entered into relational tables for

analysis in the project GIS. Appendix C provides a complete list of artifacts and eco facts collected during field survey.

CHAPTER 5

ANCIENT CITIES AND WATER: A REVIEW BY DISTRICT

Introduction

During nine and one-half months of fieldwork beginning in January 2001, I investigated and mapped, 42 *aguadas*, three *aguaditas*, three *akalchens*, one *bukte*, one *cañada* a type of canal, three canals including one moat, 20 caves, 68 *cenotes*, 88 *chultunes*, one dam, two sea estavellas, nine springs, five *haltunes*, 51 wells, five *rejolladas*, five *sartenejas*, and several lakes at 32 ancient Maya settlements in the region. In the following discussion, these features are described and discussed. Particular attention was paid to the significance of associations, micro and macro scale context and varied physical environments. To avoid confusion regarding the numerous sites, feature types and physiographic districts involved in this study, and keep the analytical commentary closer to the data, argument regarding the significance of site-specific findings to the research problem is included within the individual site divisions of this chapter. This enables the reader to better relate the significance of data from each site.

In instances where resources or features were surveyed and analyzed by other researchers, for example the canals and

aguadas of Edzná, sites and features were revisited or surveyed for instructive and comparative purposes. Thus, observations about these sites were limited to quantitative or qualitative remarks and a brief summary of published findings germane to solving the research problem. Where appropriate, calculated densities of features per square kilometer of mapped site area are included. This format facilitates comparison of frequencies of a particular adaptive strategy from various sites throughout the study area.

Within the chapter sites are presented by physiographic district. Discussion of individual sites in each of the eight regions surveyed includes comments regarding the principal questions posed in the introductory chapters. As opposed to listing the characteristics for physiographic district in a separate introduction, in most instances general descriptions and specific site data are presented as part of the discussion by site. Where data from existing maps and publications as well as my information are sufficiently developed to complete statistical calculations, for example Calakmul, an attempt was made to move beyond descriptions.

Bolonchen District

Acanmul

Acanmul, a third ranked site (Garza and Kurjack 1980), is located approximately 48 kilometers north-northeast of the modern City of Campeche, Campeche, Mexico and 12 kilometers southeast of the Maya town of Hampolo in the Bolonchen District (Wilson 1980). Wilson characterized the Bolonchen (Figure 5.1) as an area of broad cone-shaped hills having ridges of relatively high relief (Figure 2.2). Portions of the District, including the area where the site of Acanmul is situated, have low relief, meandering streams, *bajos* or swamplands, and relatively thick alluvial deposits. The Palace on the northern edge of the central precinct is located at 16Q 779954mE, 2203119mN UTM, 19° 54' 15.575" North, 90° 19' 33.859" West. Depth to phreatic measurements in the Bolonchen District average less than three meters on the northwestern boundary to in excess of 140 meters near Nohcalab, a town located close to the northeastern boundary of the district. Acanmul is in the central portion of the five to ten depth to phreatic zone established by the National Water Commission for the State of Campeche (Direccion General de Administracion y Control de Sistemas Hidrologicos Direccion de Aguas Subterraneas 1989b).

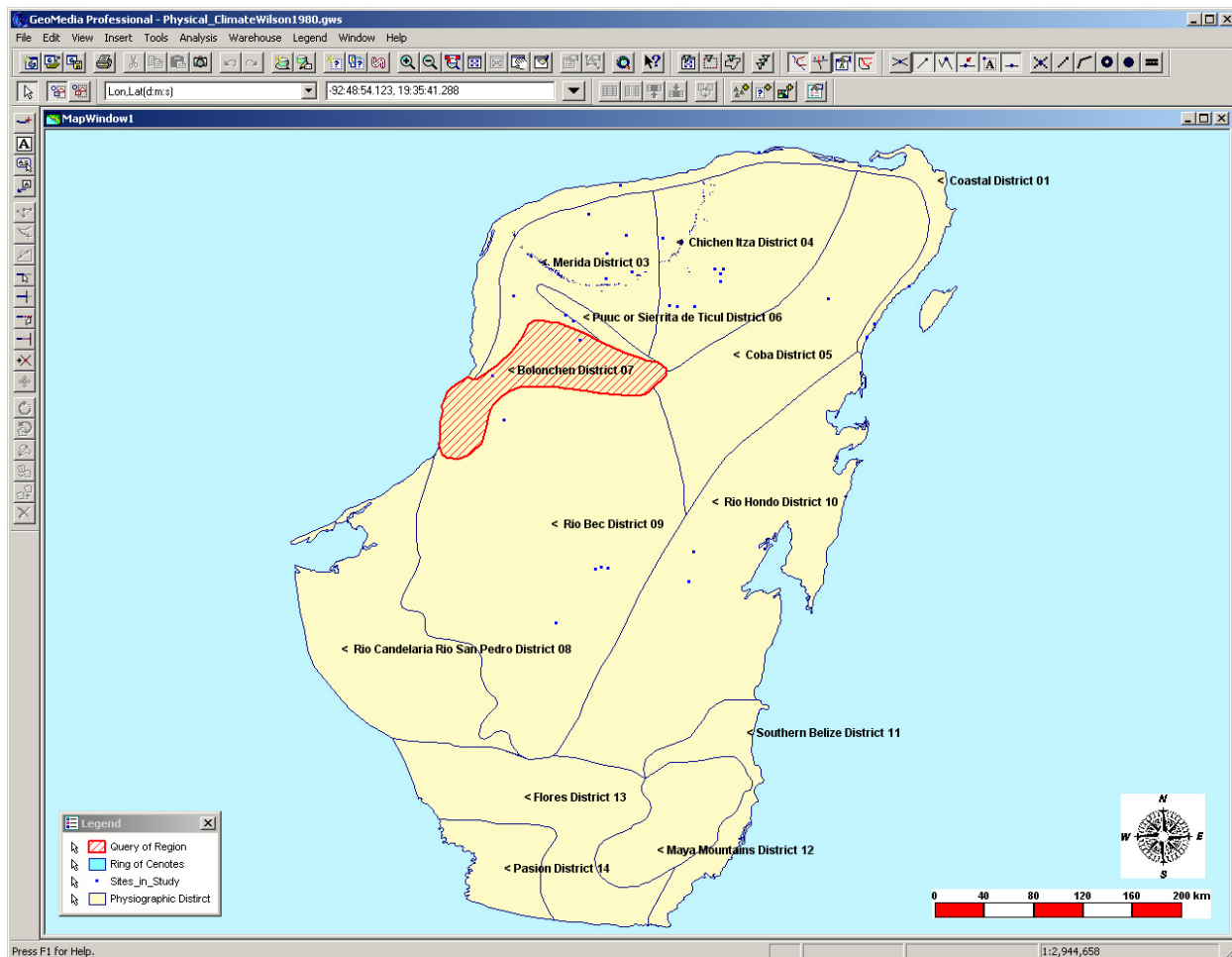


Figure 5.1 Wilson's (1980) Bolonchen District in the project GIS.

The settlement of Acanmul (Figure 5.2) is situated in a wide valley that forms a gap in the chain of hills that run from Maxcanu to Campeche. The valley is drained by an arroyo that meanders across grassy savanna and *bajos*. During the Colonial Period, the arroyo was known as the Rio Homtun (Roys 1957). Today, this stream is known as the Rio Verde "Green

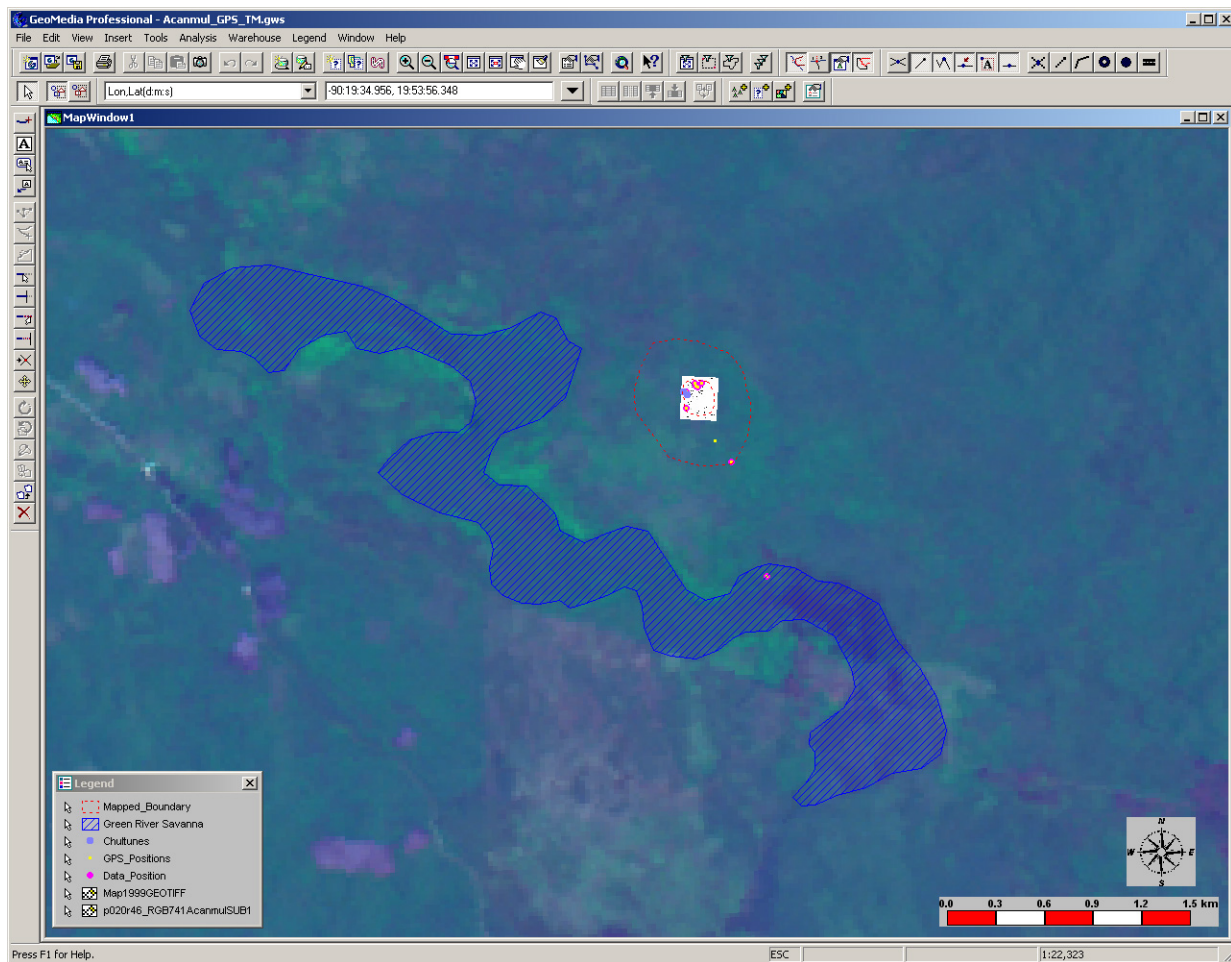


Figure 5.2 Map of Acanmul in the project GIS. Blue shaded area indicates the Rio Verde Savanna. Landsat TM courtesy of NASA.

River” a toponym that characterizes the lush green grasses that cover the flood plain throughout most of the year.

For most of the dry season the arroyo is a muddy swamp that might flood to a depth of two meters during the height of the rainy season (Pollock 1980). During survey, the department of transportation was making an effort to elevate the unpaved road passing through the Green river area to Acanmul, situated

above the floodplain. Most likely the ancient inhabitants of Acanmul did not experience water stress related problems.

The geography of Acanmul suggests that if water management beyond draining flood prone areas was necessary to provide water to the general population, excavation of wells was one of several options available to the inhabitants. Production from wells for the most part would not have been seasonally interrupted like *chultunes*. Therefore ancient wells should be part of the cultural landscape as well as storage systems.

Although a revised and more detailed map of Acanmul exists, I was unable to obtain a copy for this project. Therefore the 1999 preliminary site map (Ojeda Mas 1999) was used as a guide for field survey. The mapped portion of the central precinct on the 1999 map represents an area covering less than 0.10 square kilometers. This figure grossly understates the true size of Acanmul. Like other sites in similar environments such as Dzibanché and Kohunlich, settlement units are clustered in slightly elevated areas surrounded by seasonally inundated savanna. Quite likely, the ancient inhabitants endured seasonal floods. By extending the boundary 500 meters to the southeast to include an ancient well, the site coverage increases 0.50 square kilometers.

Pollock (1980) did not find *chultunes* at Acanmul. Ojeda Mas (1999) indicated one *chultun* in the central precinct on the 1999 map. I located the Ojeda Mas *chultun* and a second in the central precinct. Pollock mentioned that his guide reported an ancient well but he was unable to locate the feature during his visit. I recorded the position of a well near the ruins of an abandoned Hacienda 320 meters south southeast of the site core, but cannot be certain whether or not this is the well Pollock mentioned. Circular stones that formed the original opening are visible beneath a rectangular capstone presumably set in place during recent times (Figure 5.3).

There are four major groups at Acanmul having monumental architecture from Late Classic and Early Postclassic Periods. Both *chultunes* were in the central precinct zone. Although the *chultunes* are associated with vaulted architecture they varied little from others observed in common domestic contexts. Heber Ojeda Mas and Adriana Sanches Lopez placed the principal occupation of the site to a period from the Classic Period (A.D. 300 - 600) through the Terminal Classic Period (A.D. 800 - 1000) by analysis of pottery collected from two test pits excavated in Structure 1, the Palace (Ojeda Mas 1999, 2000; Ojeda Mas and Sanches Lopez 2001). The earliest ceramics recovered from Acanmul are Preclassic Period Tihosuco Complex



Figure 5.3 Well at Acanmul.

ceramics dating from 800 B.C. to A.D. 100. The latest pottery from *chultunes* and structures are Hocaba Complex ceramics dating to the Early Postclassic Period (A.D. 1200 to 1300), suggesting a long sequence of occupation. The largest portion of total ceramics found in water management contexts are Cehpech Complex ceramics dating to the Terminal Classic Period (A.D. 800 to 1000). The higher frequency of Cehpech Complex ceramics suggests higher usage of *chultunes* during the Late and

Terminal Classic Periods. Survey at Acanmul failed to reveal fortifications, controlled water resources, or evidence to suggest differential access to certain locations existed. There is no reason to suggest hydrological management supported elite authority or that resource circumscription limited potential for site expansion and development as evidenced by the subdivision of existing spaces and a notable absence of peripheral settlement features.

Sayil

Although Acanmul and Sayil are both located in Wilson's Bolonchen District, inhabitants of each were faced with dissimilar microenvironments and responded in different ways that seem be unrelated to differences in settlement size. Sayil, is a second-ranked site (Garza and Kurjack 1980) situated 90 kilometers south of Merida, Yucatán. The center of architectural mass at Sayil is located at 16Q 222827mE, 2232998mN UTM, 20° 10' 27.986" North, 89° 39' 06.875" West. Average depths to the aquifer in the area range between 50 and 90 meters (Direccion General de Administracion y Control de Sistemas Hidrologicos Direccion de Aguas Subterraneas 1988). Wells were not an option for the ancient inhabitants of Sayil. The mapped portion of Sayil (Sabloff 1991b) covers an area measuring approximately 3.25 square kilometers (Figure 5.4).

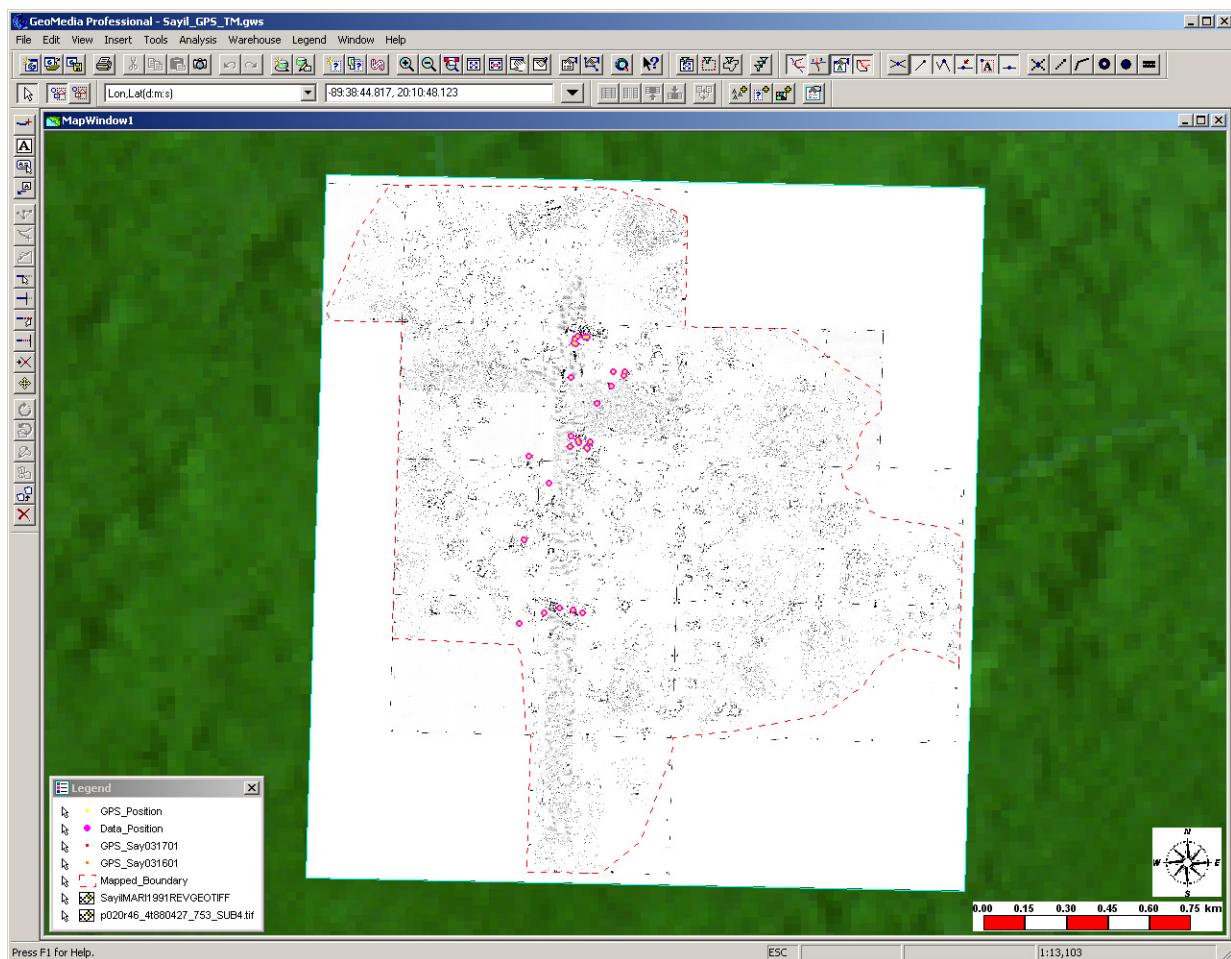


Figure 5.4 Map of Sayil in project the GIS, adapted from Sabloff and Tourtellot (1991). Landsat TM courtesy of NASA.

Pollock (1980) reported three dates from the site, A.D. 810 by Proskouriakoff (1950), A.D. 720 ± 60 by Tamers (1969), and A.D. 730 ± 80 by Damon et al. (1974). Except for one instance of Chicanel Complex, Flor Cream Group pottery dated to a period from 300 B.C. to A.D. 250/300 discovered in an on-platform *chultun* 179 meters southeast of the North Palace structure, pottery from water features includes Cehpech, Sotuta, and

Hocaba-Tases Complex Ceramics representing a period of use from A.D. 800 to 1450. Cehpech and Sotuta Complex (A.D. 800 to 1000) accounted for the highest percentage of ceramics collected. Dates from my collection agree with those published by Pollock (1980).

Although the area surrounding the Sayil is considered part of the Puuc region, the site is situated near the northern border of Wilson's Bolonchen District where three districts including Merida and the Puuc converge. Although the GIS enabled me to plot geographic location to the centimeter, characterizing physical environments based upon widely distributed observations is not as precise. Physical and cultural traits from all three districts exist at most of the Puuc sites surveyed for this study. Wilson described the area as tropical savanna with local relief to 100 meters, broad cone-shaped hills, caves, and no substantial permanent sources of surface water. Many Bolonchen sites are situated along valleys having moderately developed tracts of kancab soil and seasonal water sources (Dunning 1992:105). For a more comprehensive description of the physical environment in the Puuc Region see Dunning (1992).

A large body of scholarly papers and publications concerning settlement pattern and water systems at Sayil is

available. Fieldwork at Sayil provided the opportunity to review much of what is already written. Although there might be earlier accounts, the first reference to Sayil was found in Stephens (1988). Maler (1997), Shook (1935), and Pollock (1980) wrote early accounts of the site as well. Sabloff and Tourtellot (1991a) conducted extensive survey and mapped the site from 1983 to 1988. During fieldwork, the Sayil Archaeological Project under Sabloff and Tourtellot mapped and recorded approximately 2,500 features. I adapted and used the Sayil map as a guide for survey at the site. McAnany (1990) used water storage features to construct population estimates for Sayil. Dunning (1992) discussed Sayil within the context of a study of the structure of Puuc communities.

At Sayil, *chultunes* supplemented a few *aguadas*. One of the three small *aguadas* reported by Sabloff and Tourtellot (1991a, b) was located. Calculated *chultun* densities from Sayil are among the highest recorded during field operations. McAnany (1990:270) reported 256 on-platform and 51 off-platform *chultunes*, a total of 307. The 307 *chultunes* distributed throughout an area covering approximately 3.25 square kilometers generate a calculated density of 94.64 per square kilometer. The literature survey failed to reveal any mention of ancient wells at Sayil.

Sabloff and Tourtellot (1991a) recorded 269 on-platform, 55 off-platform, and ten "storage" *chultunes*, a total of 334. Rather than attempt to distinguish *chultun* function on a feature-by-feature basis all documented *chultunes* regardless of specific functional class were used to calculate feature density. The additional *chultunes* Sabloff and Tourtellot reported increase frequency to 102.96 per square kilometer. Clearly, *chultunes* represented a major adaptive strategy employed by the inhabitants of the site. No evidence such as walled in resources to suggest differential access to *chultunes* was found during field survey. However, *chultunes* are found on platforms. If platform boundaries represent private space, a highly likely possibility, then on-platform *chultunes* were owned features similar to our privately owned wells. You probably would not refuse to give a stranger a drink of water from your well, but you would certainly expect them to ask permission. The Maya having *chultunes* on their platforms might have responded similarly.

Some evidence exists to suggest that certain elite spaces contained more elaborate *chultunes* than those found in off platform contexts. More elaborate variants might be related to



Figure 5.5 Plastered mouth of sealed *chultun* at Sayil.

conditions associated with constructed *chultunes* on platforms and terraces. One *chultun* on a platform 211 meters west of the Mirador appeared to be intentionally sealed (Figure 5.5).

During excavation, the capstone was removed, the catchment area cleared, and the general area and interior surfaces photographed. Excavation revealed that a substantial portion of the plaster lining remained intact. Variation in complexity of architecture at Sayil suggests a stratified system existed at

the site. Both elaborate and simple *chultunes* were found in elite contexts suggesting that water management at the site did not contribute to social inequality. Furthermore, no evidence of a concentration of elite vaulted architecture near the *aguada* I located was noted.

Chichén Itzá District

Chichén Itzá

Chichén Itzá is a first order site (Garza and Kurjack 1980) situated in north central Yucatán. Like many sites in the region, Chichén Itzá exhibits evidence of Preclassic Period occupation. Chichén Itzá and other settlements in the northern peninsula were occupied for centuries after the Classic Period sites to the south were abandoned. The Grand Plaza at Chichén Itzá is located at 16Q 336626mE, 2287858mN UTM, 20° 40' 58.893" North, 88° 34' 06.755" West. The site is near the southeastern border of Wilson's Chichén Itzá District (Wilson 1980).

The Chichén Itzá District (Figure 5.6) is characterized by as a karstic plain with relief to near 25 meters with *cenotes*, lakes, and dry depressions known to the local inhabitants as *hoyas* or *rejolladas*. Chichén Itzá, Cumtun, Izamal, and Yula are all located in the Chichén Itzá District. The northern third of the Yucatán Peninsula from the Gulf Coast south to the Serrita

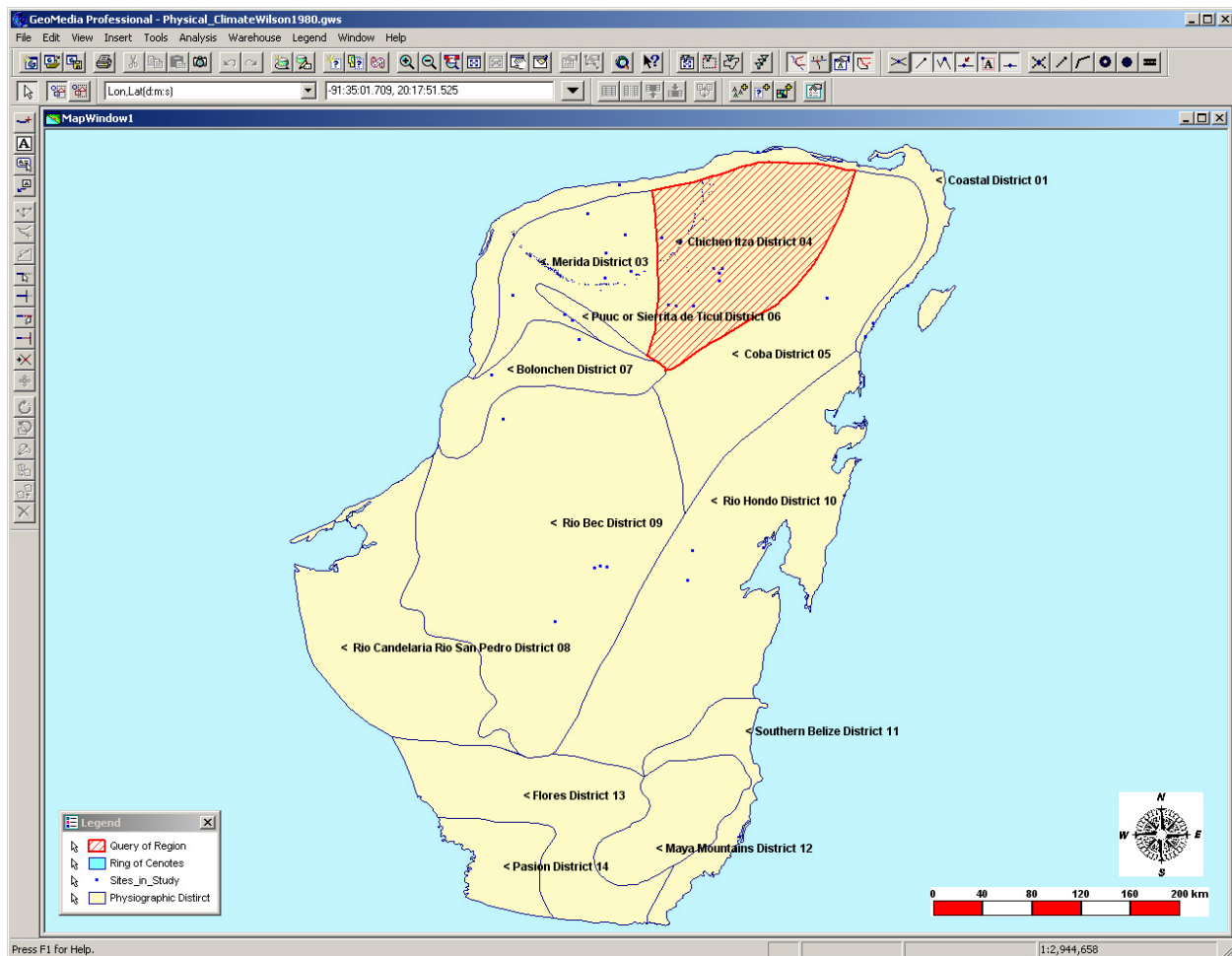


Figure 5.6 Wilson's Chichén Itzá District in the project GIS.

de Ticul is relatively level and lacking surface streams. The fractured limestone landscape is pitted and scarred by numerous solution depressions and low ridges. The phreatic in the area around Chichén Itzá occurs 20 to 25 meters beneath the surface (Dirección General de Administración y Control de Sistemas Hidrológicos Dirección de Aguas Subterráneas 1988). Depths to phreatic measurements throughout the entire district vary from

less than five meters near the northern boundary to 35 meters near the town of Peto in the south. Depth to aquifer is a significant physical variable; therefore the ancient Maya inhabiting this portion of the region had a combination of adaptive options available to them including both conservation and storage and excavation by shallow well.

A large portion of the northern Yucatán Peninsula is climate type Aw1 in the Köppen system, as adopted and modified by INEGI (2001a) and UNAM. Aw1 climates are characterized as tropical humid. The inhabitants of Chichén Itzá very likely had to adapt to a blend of the both climate types. The area receives between 1100 and 1200 millimeters of annual rainfall, most occurring during a six-month rainy season that usually begins in June and ends in November or December. During the driest months, rainfall averages less than 60 millimeters per month. Temperatures in the area average 22 degrees Celsius and typically are above 18 degrees in the coldest month. Real evapotranspiration rates reported for the area average between 1000-1099 millimeters annually just to the north Chichén Itzá to 1100 to 1199 millimeters annually within the immediate area and to its south. INEGI (2001b) reports modern day annual water deficits ranging between 400 to 500 millimeters in the area. Similar figures most likely existed in the past.

Although the bioregion is classified as savanna, a mixed grassland and woodland, Bequaert (1933) argued the area as a sub-region would be better described as dry forest. It is easy to tend toward classification of the local vegetation coverage as xerophytic. Nevertheless, the flora of this part of the peninsula has a combination of flora from tropical humid forests and dry woodlands. During the dry season, a majority of the landscape is desiccated and defoliated. The area is covered with a variety resilient woody scrub adapted to survive in dry climates. Shortly after the beginning of the rainy season, the forest develops a lush low rainforest-like canopy.

In addition to its unique architecture (Andrews IV 1965a), Chichén Itzá is known for its Sacred Cenote. The site has two large Type 1 *cenotes* (Roys 1939) inside the central precinct. Several additional *cenotes* in the general area were investigated. Chichén Itzá is 40.89 kilometers southeast of the trough or "moat" (Kinsland, Hurtado and Pope 2000; Pope et al. 1996) of the Chicxulub crater, crescent-shaped 10-kilometer wide three to five meter deep depression that contains a large number of fractures that often intersect one another. The depression juts inland approximately 90 kilometers along an axis centered near Puerto Progreso on the northern Gulf Coast to Sacalum and Tekit in the south. The trough exits the coast

at the ends of the arc in the west some 22 kilometers west of Sisal and at a point centered between Dzilam de Bravo and San Felipe to the east. Recently, there has been an increased interest among geologists, geographers, and archaeologists regarding the relationship between Chicxulub and the crescent-shaped ring of *cenotes*, and the cultural landscape.

A relationship between fractures in the limestone surface of the peninsula and water features is evident elsewhere in the region. A series of lakes and caves follow a feature known as the Holbox fracture zone that extends from Punta Caracol on the northeast coast of Yucatán south southwestward beyond the archaeological site of Coba. Lakes in the Coba region are attributed to Holbox fracture.

The site of Chichén Itzá is mentioned in early Spanish records describing the Yucatán Peninsula. In 1566, Friar Diego de Landa (1978) described and sketched the four-sided stepped pyramid El Castillo and commented on various offerings and the a temple at the Sacred *Cenote*. Several centuries later, on March 11, 1841, Stephens and Catherwood visited the site (Stephens 1988). The Stephens expedition published the earliest known map of Chichén Itzá in 1843 (Stephens 1988). Maudslay (1892a, b) and Holmes (1895a, b) published sketch maps of the site as well. In 1924, archaeologists from the Carnegie

Institution of Washington launched a major investigation of the site under the direction of Morley (Ruppert 1935, 1952a, 1954; Sharer 1994). Shortly afterwards, the Carnegie Institution opened additional projects in southern portions of the peninsula and Guatemala. The Carnegie Institution published maps and sketches of the site in 1932, 1934, and 1952 (Morris, Charlot and Axtell Morris 1931; Ruppert 1935, 1952a). Lincoln (1990b) mapped sections of the site for his doctoral dissertation. Using the known system of causeways and similarities between various architectural styles and settlement units, Peter Schmidt, Director of the Chichén Itzá Archaeological Project, redefined the site boundaries established by the Carnegie Institution to include areas outside those mapped under Karl Ruppert's supervision (Schmidt 1995). The revised polygonal increased the site from the 5.5 square kilometers covered by the Carnegie map to an area covering approximately 20.55 square kilometers.

In 1994 Cobos surveyed part of the site. Between 1995 and 1997, Cobos and Winemiller under authority of the Chichén Itzá Archaeological Project surveyed unmapped portions of the site as defined by Schmidt (1997). Winemiller added features in 1998 and 2001 (Winemiller 1998, 2000a, b, 2001; Winemiller and Ochoa Winemiller 2001; Winemiller, Jones and Ochoa Winemiller 2002).

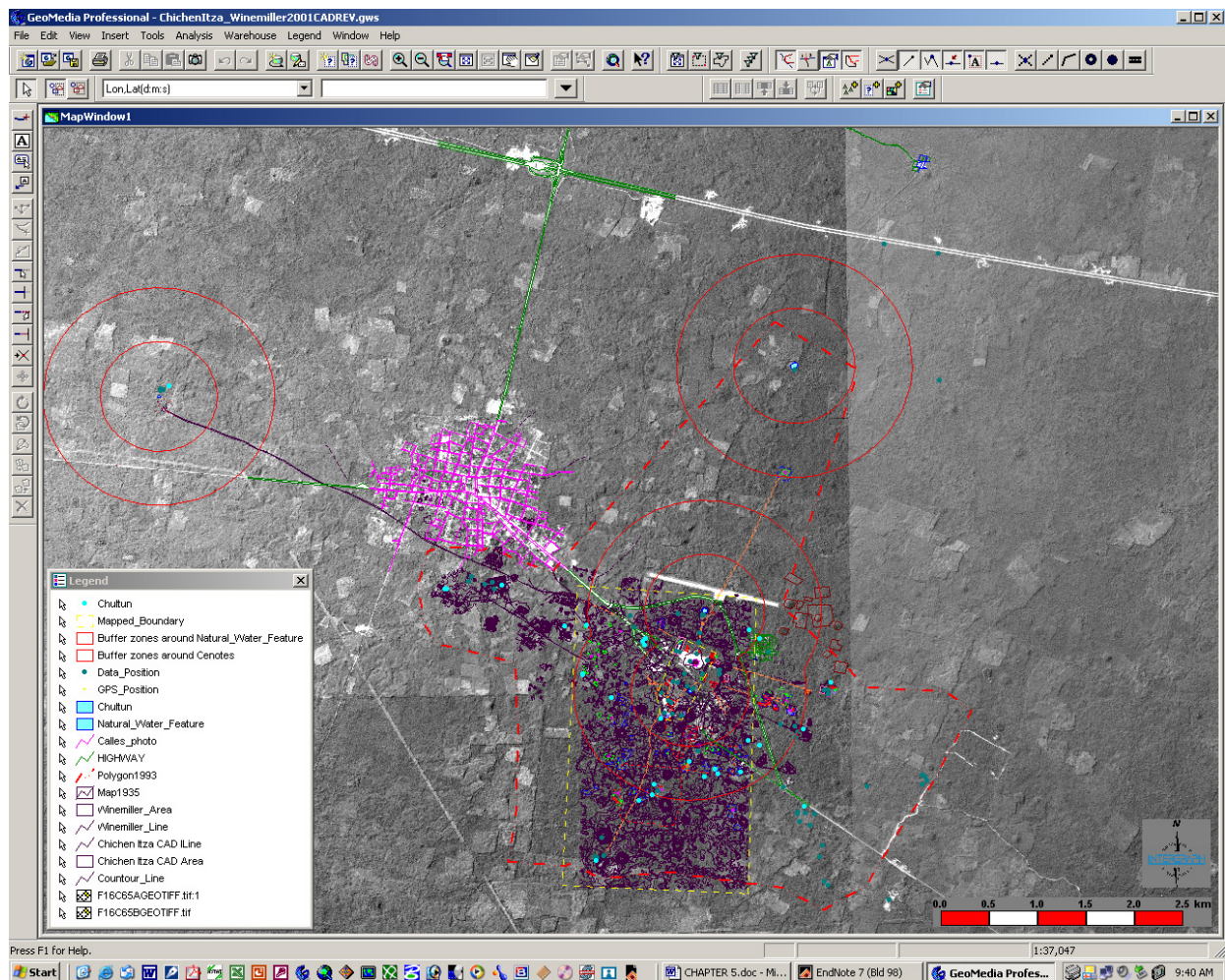


Figure 5.7 Map of Chichén Itzá in the project GIS.

Figure 5.7 depicts the consolidated maps of Chichén Itzá. The dark rectangular area is Ruppert's (1952) map. The red dashed line represents Schmidt's polygon. The dark northwest to southeast transect running through the Carnegie rectangle is the Cobos Winemiller map. Red circles represent 0.50 and 1.0 kilometer buffer zones around cenotes. The buffer zone in the extreme northwestern portion of the map is the site of Cumtun.

Smaller light blue circles represent *chultunes*. Architectural groups and structures at Chichén Itzá are linked together by a system of causeways (Cobos and Winemiller 2001). To date the longest causeway links the central precinct of Chichén Itzá to the site of Cumtun, see map. The central precinct covers an area of 0.50 square kilometers.

During field survey at Chichén Itzá, data from seven *cenotes*, Cumtun, Holtun, Kanyuyum, Poxil, Sagrado, Xchil, and Xtoloc; four large *rejolladas*, Abuelita, Holtun, Naranja, and Thompson; four wells, the Northwest Group, near the Fecha Group, in *Rejollada* Abuelita, and at San Felipe Nuevo; one *haltun* in the *Chultun* Group; and 30 *chultunes* of varying shape and complexity. I observed 14 *chultunes* in off platform contexts, ten on platforms with evidence of unvaulted structures, and six on platforms supporting the remains of vaulted structures were recorded.

The two Type 1 *cenotes* (Roys 1939) inside the central precinct might have had different functions. The Sacred *Cenote* was used ritually (Coggins and Shane III 1984; Piña Chan 1970, 1980; Tozzer 1957). Alternatively, *Cenote* Xtoloc functioned as a source of water for the inhabitants. Both have associated temples situated on or near rims. *Cenote* Xtoloc is more funnel-shaped rather than vertical-walled like the Sacred *Cenote*

making it, although treacherous, accessible on foot. Water in the Sacred Cenote is inaccessible by foot. At Chichén Itzá, the subterranean river flows north toward the coast. Xtoloc would have been prone to pollution and pathogens introduced into the water by ritual activities taking place at the Sacred Cenote. However, neither source would have escaped contaminants introduced through fractures by living organisms or animals falling into the water.

According to Piña Chan (1980), the water surface in the Sacred Cenote is 22 meters below the ground surface. The water in Cenote Xtoloc measures the same. At Cumtun the water surface is 13.96 meters, at Holtun 17.63 meters, Poxil 40 meters, Kanyuyum 20 meters, and Xchil 30 meters. Water depths in the *cenotes* of Chichén Itzá vary between 50 meters at Cenote Xchil and 9.6 at Cenote Holtun. Modern inhabitants use several *cenotes* including Cumtun and Poxil as sources of water. The landowner at Poxil pumps water from the *cenote* for use in his residence and for livestock. Figure 5.8 illustrates the rectangular mouth and brocal observed at Cenote Holtun. The natural opening of this Type 2 *cenote* Roys (1931) was most likely modified and the brocal added during the Colonial Period. Similar modifications to Type 2 *cenotes* (Roys 1939) were found at Mayapan as well. The *cenote* at Holtun is the only



Figure 5.8 Rectangular opening and brocal at *Cenote Holtun*.

Type 2 *cenote* observed at Chichén Itzá; the others observed were Type 1 in form.

With the exception of the *Cenotes* Sagrado, Xtoloc, and Holtun the other *cenotes* were surrounded by modest vaulted and nonvaulted architecture. Clearly, the *Cenote* Sagrado and Xtoloc serviced the needs of the inhabitants of the central precinct. Although they might have existed in the past, no references in the literature or evidence of *chultunes* on the Central Plaza

were discovered. I surveyed one undocumented *chultun* 50 meters south of Las Monjas. This is the closest *chultun* to the central precinct. The notable absence of *chultunes* in the core suggests that natural water sources were sufficient to support the population in the immediate area. It is uncertain whether or not the residents of this area considered these features owned property. This survey revealed a different pattern beyond 0.50 kilometer of the *cenotes*. The frequency of *chultunes* increases rather dramatically then decreases beyond a one-kilometer radius. Falloff beyond one kilometer is both related to intensity of the survey and the transition from densely populated core areas to the periphery.

Cenotes near Chichén Itzá were highly desirable locations for settlement. All the *cenotes* are associated with architectural remains. Several groups of non-vaulted structures were observed within 50 meters of the *cenote* at Cumtun; one included a double-mouth *chultun*. The remains of platforms supporting vaulted and unvaulted structures surround *Cenote Poxil*, but no large mounds exist in the immediate area. A relatively dense complex of vaulted and unvaulted structures and platforms was found on the southeastern rim of *Cenote Kanyuyum* as well. In general more densely packed concentrations of buildings were found adjacent to *cenotes*. Beyond these

areas, settlement density diminishes to resemble a pattern similar to Bullard's (1960) clustered dispersed. This pattern suggests the earliest inhabitants preferred natural water features and established settlements in these areas. As population growth and settlement expansion pressed beyond a certain distance from the resource, perhaps one kilometer, other adaptive options such as the construction of *chultunes*, although not absolutely necessary solved certain problems. Well-documented ceramic evidence to develop a chronology for this scenario is non-existent for the site.

Rejolladas are funnel-shaped sinks morphologically similar to *cenotes* but they do not contain large reservoirs of standing water. They might have been as attractive to early settlers as large Type 1 *cenotes*. Two very small partially exposed pools of water were observed under rock ledges in *Rejollada* Naranja and *Rejollada* Thompson. Water drips or runs into these pools from cantilevered limestone above the small reservoirs. The modern day inhabitants collect *zuhuy ha'*, sacred water from these places for rituals such as the *Cha Chaac* rain ceremony. I recorded and photographed several quern- shaped vessels, used by the Maya to collect water dripping from ledges above a pool in *Rejollada* Thompson, see Figure 3.1. The querns are not exactly like the miniature *metates* from Balankanché Cave



Figure 5.9 Offerings at Balankanché Cave.

reported by others (Andrews IV 1961). Figure 5.9 shows miniature *metates* and vessels found in a sealed chamber inside Balankanché Cave. The spatial arrangement of vessels and *metates* in the photo is not as found. The notable difference in form alludes to functional differences. Clearly, the *metatitos* at Balankanché were not fashioned to hold water. By contrast, the quern-like vessels observed at *Rejollada* Thompson and elsewhere appear to be replicas of a fairly common large class of *metates* often found in domestic spaces. The large quern-like *metates* are typically filled with water during the rainy season (Figure 5.10). We need to rethink the function of the ubiquitous so-called large *metates* found throughout Yucatán to include perhaps a water-related task such as soaking maize.

Though the dripping water at *Rejollada* Thompson is considered sacred for ritual, it is also considered by the



Figure 5.10 Large *metate* in a domestic space at Dzibilchaltún.

modern day inhabitants to be equally suitable consumption on a hot Yucatán afternoon. Essentially, the sacredness of *zuhuy ha'* is both constructed and situational. My observations and ethnographic data suggest virtually any water coming from an underground source, or for that matter falling from the sky might be sacred under the right circumstances.

The physical environment provided the inhabitants with the opportunity to extract water by constructing wells. Several

wells were found at Chichén Itzá. Excavating 20 to 25 meters through limestone would have been labor intensive and a difficult undertaking. In areas where depth to aquifer levels approached the limits of a society's technology, for the Maya a stone tool tradition, wells should become less attractive options and thus less frequent in the archaeological record. Moreover, wells should occur more frequently in *rejolladas* or depressions where lower relative elevations provided opportunistic sites for excavation to the aquifer.

Schmidt (1998) depicted a well in the bottom northern edge of a small *rejollada* to the east of the Akab Dzib a structure believed to be a palace. I was unable to verify the location of this well during fieldwork nor gather information about its dating. Beyond recording the well location, few other comments can be made about this particular feature. Two of the four wells surveyed at Chichén Itzá, one just west of the Northwest Group and another in *Rejollada* Abuelita are clearly ancient. I cannot be reasonably certain about the other two. Including the well noted by Schmidt, the density of wells in the area mapped by the Carnegie Institution totaled 0.737 per square kilometer. Well density in a zone defined by concentric rings at 0.5 kilometers and 1.0 kilometer beyond *Cenote* Xtoloc totaled 0.912

per square kilometer. One well, the Schmidt well is within 500 meters of *Cenote Xtoloc*.

Unlike the wells investigated at Dzibilchaltún, the well shaft was constructed of rough cut-stones and mortar; see Figure 3.9. This technique was required at the bottom of *rejolladas* where deep unconsolidated deposits of soil and organic material build up over time. Stone and mortar was essential to extend the necks of *chultunes* built in areas where a layer of unconsolidated material overlies consolidated limestone, or on platforms filled with unconsolidated material as well. A well at *Rejollada Ixbaac* and several on-platform *chultunes* at Chichén Itzá were constructed using the stone and mortar technique. Figure 5.11 shows a *chultun* from Edzná that demonstrates that this practice was commonly utilized in the Bolonchen and Rio Bec Districts as well.

Thompson (1897b) noted stone and mortar construction at Labna. Zapata Peraza (1989) cited on platform stone and mortar *chultunes* at Labna. Analogous physical features in other settings required extended *chultun* necks as well. Portions of valley floors in the Bolonchen District lying between broad cone-shaped hills known as *Uitezs* (Casares 1905) are analogous to strata at the base of *rejolladas*. For a thorough description of stratigraphy in the Bolonchen district see Dunning (1992).



Figure 5.11 *Chultun* at Edzná with stone and mortar neck.

The Maya also excavated *chultunes* on exposed outcrops of caprock, digging into the underlying soft and permeable *sascab* (Figure 5.12). In these instances, a ring-stone or several courses of cut stones might have been added to the opening to form a brocal or curb. Some *chultunes* contain remnants of plaster linings and others contain no evidence of liners. This particular variant presents a strong case for the notion that



Figure 5.12 Double *chultun* at Cumtun excavated in the caprock.

some *chultunes* functioned for purposes other than water storage.

Developing taxonomies or refining the typology of natural features such as *cenotes* is not the object of this paper. Instead, my purpose is to reveal patterns of spatial distribution, frequencies by type, and incidence of definable adaptive strategies in various environmental zones. Unless a stylistic or technological variation in *chultun* design,

particular technology, or contextual variant significantly enhanced the overall effectiveness of a hydrological regime or settlement strategy, time spent reviewing types and existing typologies is intentionally limited.

When necessary to refer to a particular type I cite Zapata Peraza (1989). Her thesis provided a generalized four-type illustrated classification of *chultun* types from Chichén Itzá and sites throughout the Puuc. With few exceptions, Zapata-Peraza's system can be applied or slightly modified to accommodate features found throughout the study area. One variant that is not mentioned in Zapata Peraza, are features known as *sascab*-pits (Winemiller 1996, 1997).

Three of the 30 *chultunes* surveyed at Chichén Itzá appear to be unique to the settlement and must be considered as innovative adaptive approaches. One was constructed on a platform in the Fecha Group 1.25 kilometers south southwest of the Central Plaza. The *chultun* (Figure 5.13) is positioned between two Florescent Puuc style vaulted buildings, the Casa de Caracoles (5C6) and Temple of the Owls (5C7) Ruppert (1952a). Unlike most *chultunes* with plaza or platform level catchment basins that funneled rainwater from horizontal surfaces into subterranean chambers, the 2.5 meter diameter round catchment basin of this feature is elevated 75



Figure 5.13 Restored *chultun* in the Fecha Group, Chichén Itzá.

centimeters above the platform. A rooftop channel stone on the Casa de Caracoles was positioned to direct rainwater into the catchment basin 3.5 meters below. In addition to the *chultun*, a drain (Figure 5.14) was recorded 11 meters north of the entrance to the Casa de Falos Ruppert. This drain appears to have channeled rainwater away from the entrance to the adjacent structure. Ruppert (1952a, b) did not mention a drain on his map. He does include a photo, his figure 5.9, of a drain in the



Figure 5.14 Left Casa de Falos, Right Caracol Ruppert (1952).

west court of the Caracol, Structure 3C15 (Ruppert 1952a) that opens into a 13 centimeter square masonry canal leading northwest under the platform. Elaborate drains such as the two mentioned above were found in an elite context. I did not observe sophisticated drainage systems in groups having nonvaulted structures at Chichén Itzá or at other sites in the sample.

The remains of two additional *chultunes* similar to the Fecha Group *chultun* were found at Chichén Itzá. One is located in the Extreme East Group 1.275 kilometers east southeast of the Central Plaza and the other 0.65 kilometers east southeast of the western edge of the Grand Plaza adjacent to the remains of a Patio Gallery structure in the northern portion of San Felipe Nuevo.

Zapata Peraza described and sketched a *chultun* similar to those mentioned above. However, her locational data and description are problematic. She described *Chultun* No.5 as two kilometers east of El Castillo on Structure 2D5 (Ruppert 1952b) inside the area of San Felipe Nuevo. This direction and distance would place the *chultun* beyond but close to the Extreme East Group. Structure 2D5 is located one kilometer south of El Castillo on Platform Ho' Che with a *chultun*. Lincoln (1990a, b) investigated and mapped this area. The *chultun* at the Ho' Che Group appears as *Chultun* No.1 on Ruppert's 1952 map and on Lincoln's 1983 as a *sascabera*. In 1997 surveyed the *chultun* on Platform Ho' Che (Winemiller 1997) and a second time during the 2001 field season. The feature is an on-platform *chultun* but no evidence remains to suggest it is similar to the *chultun* in Figure 4 of Zapata-Peraza's thesis. The sketch is similar to the elaborate style *chultunes* noted in the Extreme East Group and San Felipe Nuevo.

Resembling *chultunes*, *sascab*-pits have circular openings measuring approximately 50 centimeters in diameter and are often mistaken for *chultunes*. *Sascab*-pits do not have cut-stone and mortar necks or mouths, catchment basins or lined chambers. Chambers in most *sascab*-pits are amorphous-and include columns and excavated niches. For a thorough discussion of *sascab*-pits

see Winemiller 1997:95-105. *Sascab*-pits are included in this section to point out that not all features labeled *chultunes* actually functioned as water storage features.

As mentioned earlier, the frequency and distribution of *chultunes* at Chichén Itzá increases beyond 0.50 kilometers from *Cenote Xtoloc*. A total of 16 out of the 19 recorded *chultunes* within the 5.430 square kilometer area mapped by the Carnegie Institution (Ruppert 1952b) occur within a zone defined by two concentric rings drawn at 500 meters and 1.0 kilometer away from *Cenote Xtoloc*. The density of *chultunes* totals 3.499 per square kilometer over the entire Carnegie area, whereas *chultun* densities in the zone defined by concentric rings totals 7.296 *chultunes* per square kilometer. *Chultun* density beyond the area outside the rings but within the Carnegie area totaled 0.927 *chultunes* per square kilometer. Additional *chultunes* and wells might exist at Chichén Itzá. Gonzalez de la Mata (2001) has been studying *chultunes* and wells for her B.A. thesis, but her data were not available to this project.

At Chichén Itzá, the Maya had access to natural water resources where they existed and employed their technology to exercise two options available to them in the Chichén Itzá District. They extracted water directly from the aquifer by excavating wells and stored water in *chultunes*. The notable

absence features in the central precinct as evidence for active adaptive strategies suggests that *Cenote Xtoloc* and perhaps *Sagrado* were sufficient and reliable sources of water for inhabitants living in the site core. A portion of the architecture surrounding *Cenote Xtoloc* is elite vaulted suggesting a preference for this location. Furthermore, access to water in this area might have been limited. Other than the locational preferences and the possibility of preferential access, no evidence to suggest that elite power was based upon the control and distribution of water was uncovered at Chichén Itzá. If the Sacred *Cenote* functioned primarily as a ritual site, access to the temple located adjacent to the rim and perhaps the entire area might have been limited to religious practitioners. Water in any large Type 1 *cenote* would be extremely difficult to exploit for purposes other than consumption. The possibility exists for control by limited access. Other than the wall surrounding the central precinct at Chichén Itzá no evidence of barriers around either *cenote* in the core remains. Elsewhere at the site, there were no resources to control.

Ceramics collected in water-related contexts are consistent with the accepted site chronology. Although I am unable to definitively identify the earliest occupational

settlement units, I collected one flat-base bowl sherd, Preclassic, Nabanche - Mamón Complex, Dzudzuquíl Cream Dzudzuquíl in *Rejollada* Naranja. According to González de la Mata (2001), Preclassic ceramics are represented in collections from excavations at the well in *Rejollada* Abuelita. These findings are consistent with the notion that *rejolladas* were favored sites for early occupations. The modern-day inhabitants of the area prefer the cool moist bases of these funnel-shaped depressions to plant a variety of cultigens. In 1996, Winemiller investigated a chamber under a limestone overhang having evidence of human habitation on the rim of *Rejollada* Abuelita (Winemiller 1997). The chamber appeared to be a shelter used by inhabitants for extended periods of time. Clearly a correlation exists between *rejolladas* and wells.

Akalchen Group

Akalchens are dark wells. The water in these caves is considered sacred, *zuhuy ha'*. The *Akalchen* Group is 3.8 kilometers northeast of the Grand Plaza at Chichén Itzá at 16Q 339029mE, 2290747mN UTM, 20° 42' 33.595" North, 88° 32' 44.687" West. The cluster of platforms does not appear on existing maps of the area. The principal platform and cluster of smaller structures covers an area of approximately 0.015 square

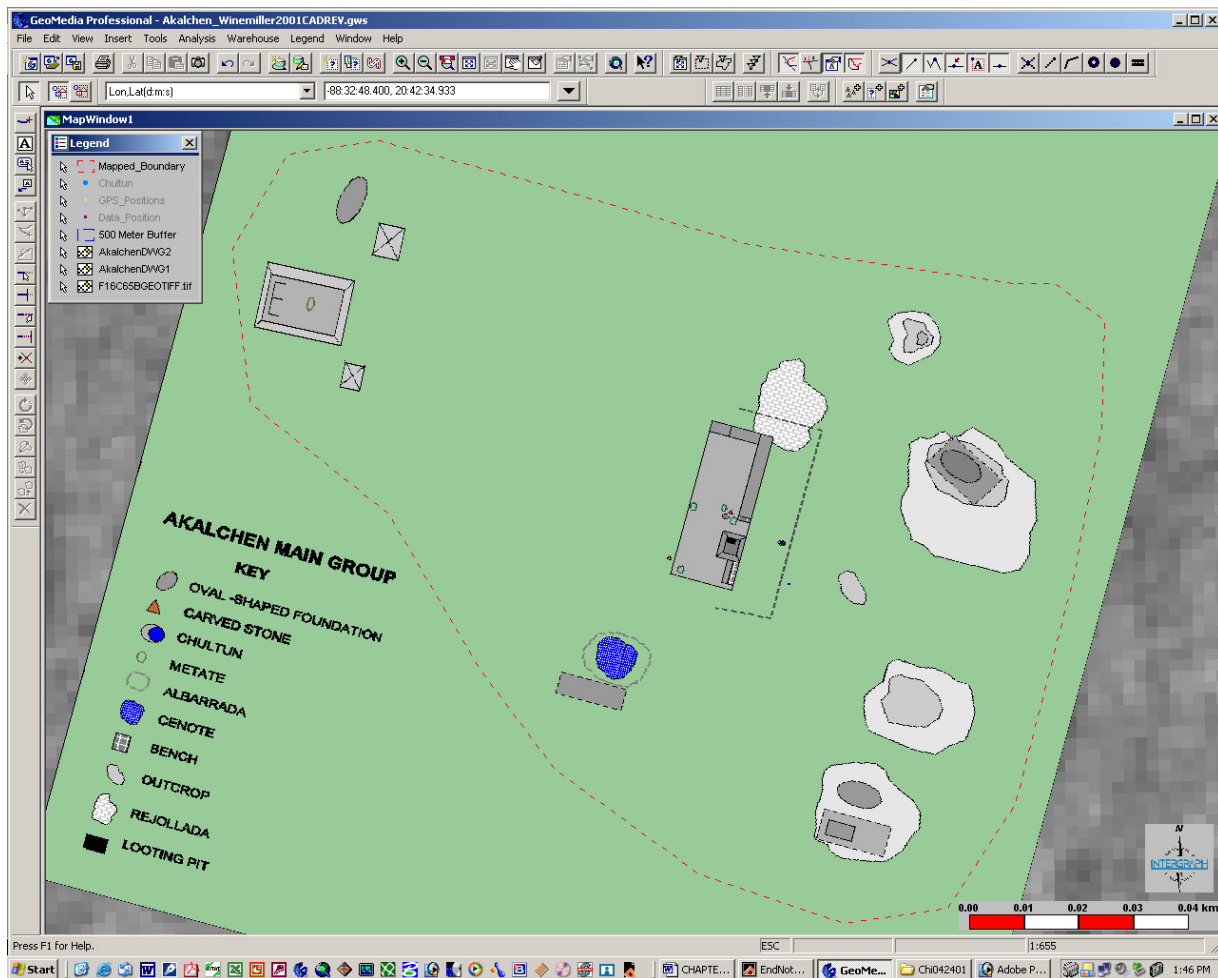


Figure 5.15 Map of the *Akalchen* Group in the project GIS, drawn by Virginia Ochoa Winemiller.

kilometers (Figure 5.15). The largest platform measures 15 meters wide by 40 meters long and supports the remains of five structures. One of the five structures had a vaulted roof. A wall enclosed a rectangular courtyard covering 500 square meters adjacent to the platform. A *chultun* is located 12 meters east of the platform inside the stone enclosure (Figure 5.16).



Figure 5.16 *Chultun* inside walled enclosure at *Akalchen* Group.

The presence of a *chultun* might indicate that the inhabitants preferred capturing water during the rainy season rather than procuring their water from the cave or elsewhere in the immediate area. The context, a walled area next to the principal platform, suggests a level of control.

The presence of a *chultun* near the *akalchen* is understandable considering the difficulty encountered

traversing the 130-meter corridor leading to the subterranean pool. Within ten meters of the entrance, the corridor descends vertically for approximately seven meters. The remaining 120 meters was littered with ceramics, a *metate*, a layer of guano, and scree from the corridor and rock ledges above the passageway. The rim of the bell-shaped, early-stage *cenote* is approximately 110 horizontal meters north northwest of the entrance (Figure 5.17). The bell-shape is a natural formation caused by weathering and subsequent collapse of bedded limestone from the chamber ceiling. The water surface is 3.2-meters below a small platform-like ledge. The reservoir depth at this point measured 25.2 meters. Although *akalchens* or caves were reliable sources of water, navigating subterranean passages presented the ancient Maya with unique challenges. Stephens (1988) described the difficulties he encountered exploring Gruta Bolonchen. Evidence that the inhabitants chose to exercise other adaptive options nearby suggests the Maya did not wholly rely on natural resources. While gathering data for this paper, I surveyed other caves in the region that were similar to the *akalchen*. Caves are common throughout the peninsula and very likely represented a viable source of water that the ancient inhabitants could have routinely exploited. Ceramics collected from different contexts in the *Akalchen*



Figure 5.17 Bell-shaped chamber of *akalchen*.

Group are Cehpech and Sotuta Ceramic Complexes, dating the occupation to a period between A.D. 600 and 1050. Vaulted architecture and proximity of the platform to the mouth suggests the inhabitants of the group might have controlled the use of water from the *akalchen* if only ritually. Approximately 40 meters to the south of the entrance, a cluster of three or four solitary structures was found. Beyond the central group, apsidal and rectangular unvaulted structures and low platforms

having no local water sources or *chultunes* are widely dispersed. Most of the small clusters are spaced more than 100 meters apart. Foot survey of the area within 500 meters of the central group at *Akalchen* produced no other visible platforms with vaulted structures. An ancient well with a four-meter diameter stone brocal 338 kilometers south southeast of the Akalche platform was discovered in the bottom of a *rejollada*. The well has not been used recently as evidenced by a layer of sediment inside the well to the top of the brocal.

Izamal

Little is known or written about the site of Izamal, Yucatan. The first order site (Garza and Kurjack 1980) is situated near the western border of the Chichén Itzá District 30 kilometers east of Aké. Izamal is connected to Aké by causeway. The site is best known for the platform named the Kinich-Kak-Moo, one of the largest platforms in the Maya Lowlands, as well as the Franciscan Convent founded in 1549 that is located near the center of town. The Kinich-Kak-Moo is located at 16Q 290302mE, 2316551mN UTM, 89° 00' 59.611" West, 20° 56' 15.033" North. The site is located near the western boundary of the Chichén Itzá District. This part of the district would fit just as easily into the Merida District to the west. Izamal is the northernmost site surveyed in this

district. Depths to phreatic measurements in the immediate area average between 10 to 15 meters (Direccion General de Administracion y Control de Sistemas Hidrologicos Direccion de Aguas Subterraneas 1988). The static level in the single well observed at Izamal measured 12 meters. Clearly excavation of wells and construction of *chultunes* were options available to the early inhabitants of Izamal. With the phreatic at or near 12 meters, we should find more wells than *chultunes*.

Friar Diego de Landa (1978) plotted the ancient town of Izamal, spelled Yzamal on an early map of the peninsula. Holmes (1895) described several structures at Izamal in some detail. Tozzer (1941) argued that Bernardo de Lizana (1893) provided the best descriptive account of Izamal. Maldonado Cardenas (1985) and Millet (1995) investigated causeways in portions of northern Yucatán, focusing on the Izamal to Aké sacbe. To date, the most thorough investigation of Izamal was undertaken by Lincoln (1980). More recently, Millet Camara has directed ongoing restoration and consolidation work at the site.

The site as mapped by Lincoln (1980) covers an area measuring approximately 3.402 square kilometers (Figure 5.18). A large area containing architectural lies beyond the boundaries of Lincoln's map. Thus, the actual coverage of Izamal was most likely several orders of magnitude above this

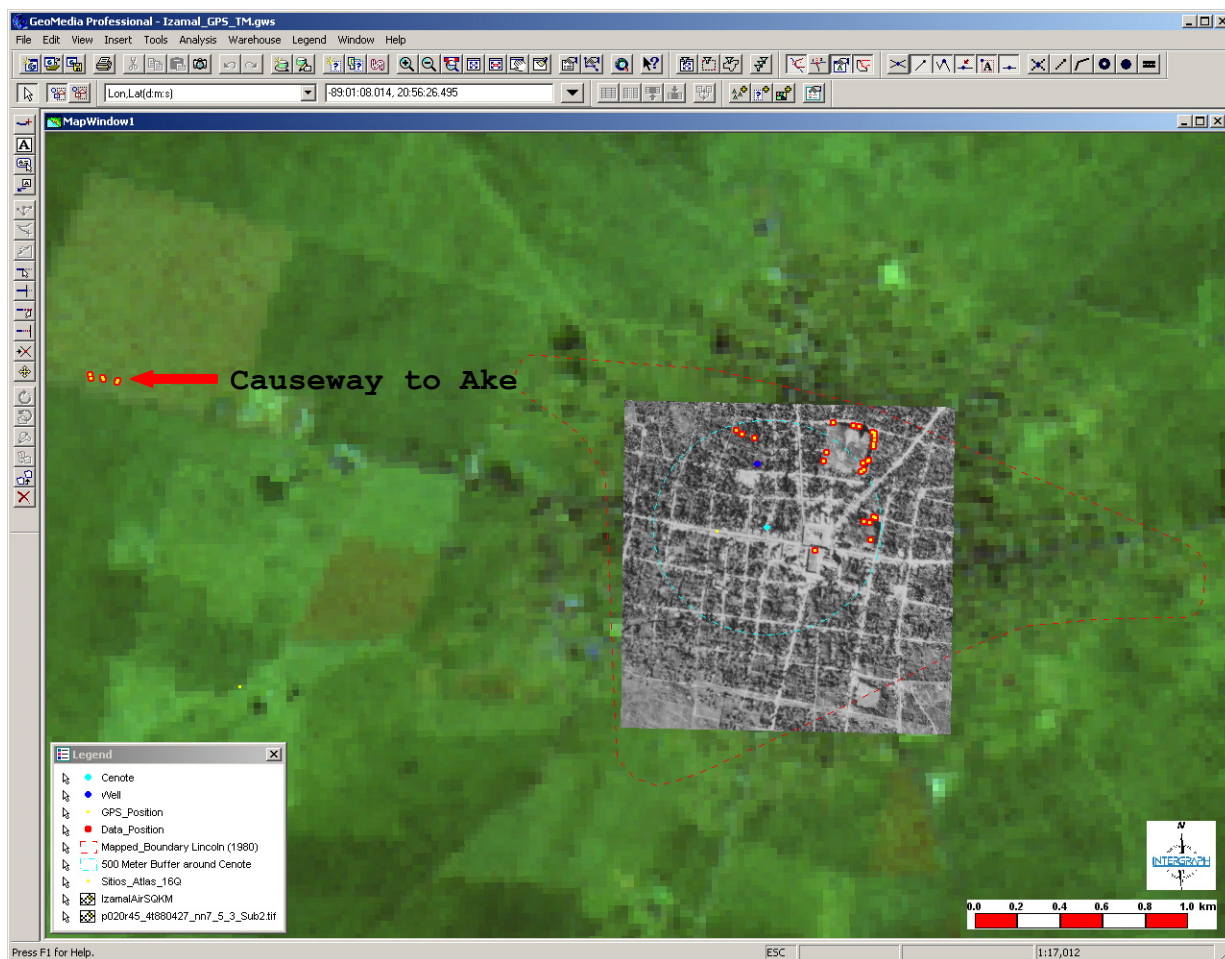


Figure 5.18 Map of Izamal in the project GIS. Landsat TM courtesy of NASA.

figure. Like other large archaeological sites such as Tiho and Acanceh situated inside the boundaries of modern day towns and urban spaces, a significant portion of Izamal was incorporated into private plots.

The town of Izamal fits the model of an idealized modern Maya checkerboard town proposed by Jordan-Bychkov and Domosh (2003) wherein a cenote is centrally located. Lincoln (1980) noted a cenote near the center of Izamal. The sink was

accessible until the early 1950's when a Spanish style house was built over it. I could not find a description or photo of the *cenote* but were able to locate several street drains that channel runoff into the sinkhole now located beneath a drugstore. Constructing a structure over top a Type 1 *cenote* similar to the *Cenote Sagrado* at Chichén Itzá or the smaller vertical walled *cenotes* such as *Cenote Cumtun* is highly unlikely. Instead, the central *cenote* in Izamal most likely was a Type 2 or Type 3 *cenote* similar to those found in the plaza of small towns and villages throughout the Yucatán. With the exception of one large platform, five of the largest features at Izamal lie within 500 meters of the *cenote*.

With the permission of a private landowner Senior Arranio Gonzalez Pat a large platform and several structures 325 meters west southwest of the Kinich-Kak-Moo were surveyed. Gonzalez Pat owns a well that is situated 32 meters south of the base of the platform. The well is the only excavated water feature measured at Izamal.

Yula

Yula is a fourth ranked site located seven kilometers south of Chichén Itzá. The foremost water feature at Yula is a culturally modified Type 2 (Roys 1939) *cenote* on the southwestern edge of the mapped site (Figure 5.19) at 16Q

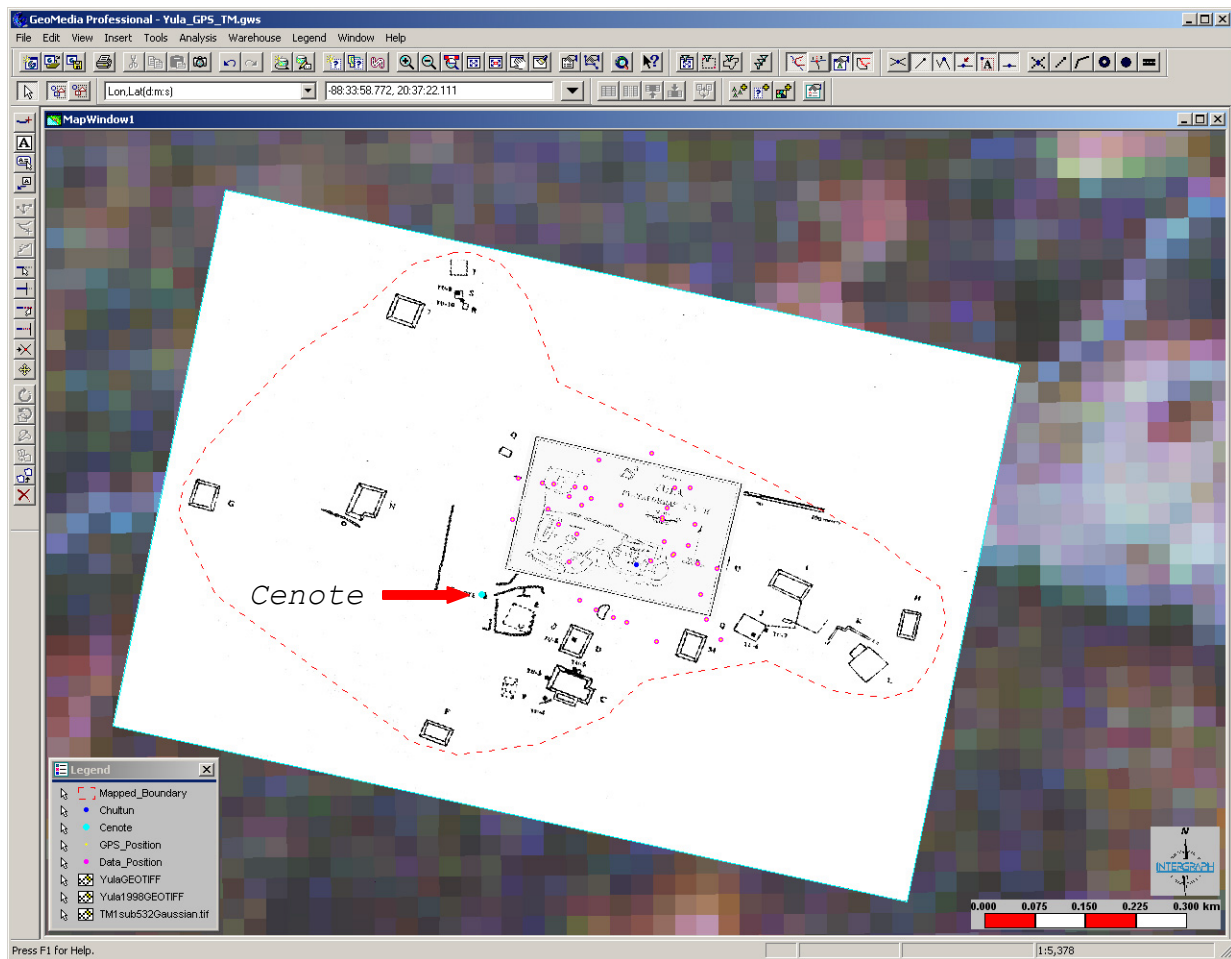


Figure 5.19 Map of Yula in the project GIS, adapted from Anderson (1998). Landsat TM courtesy of NASA.

336552mE, 2280821mN UTM, 88° 34' 06.972" West, 20° 37' 10.035" North. The caprock over the cenote was cut into a 1.5 meter wide by 2.4 meter long rectangular opening with a *brocal* or curb fashioned from several courses of cut stones. Depth measurements to the phreatic in the Yula area are similar to those at Chichén Itzá. At the time of this survey, the water



Figure 5.20 Water surface in the cenote at Yula.

surface was 19.4 meters below the opening and measured 9.10 meters deep (Figure 5.20).

Anderson (1998a, b) developed most of the information in print about the site of Yula. The site was cited in Beyer (1937), Garza and Kurjack (1980). The Anderson map depicts an on-platform *chultun* near a vaulted structure context. The *chultun* was not identified during field survey. This does not mean the feature is nonexistent, but suggests that a natural or cultural site transformation has taken place since Anderson

mapped the site. Most of the settlement of Yula lies within a 500 meter radius of the *cenote*. Many of the structures closest to the water source were vaulted. This suggests early inhabitants considered proximity to the *cenote* a desirable factor, and might indicate differential access to particular space, although the evidence for this is not overwhelming. Pottery collected at Yula represents Cehpech, Sotuta, and Hocaba Complex ceramics dating the principal occupation of the site to the Terminal Classic Period (A.D. 850 to 1200). A small occupation persisted into the Postclassic Period (A.D. 1200/1300 to 1450) as evidenced by a proportionally smaller percentage of Tases Complex ceramics.

Yula is representative of many other sites in the Chichén Itzá District that relied on passive types of adaptive strategies such as taking advantage of *cenotes* in the region, making only slight modifications to improve access or for convenience. Many sites in the district occupied areas where the phreatic, although approaching the limits of their technology, was accessible by excavation of wells. Since wells represented a reliable year-round source of water, the ancient Maya most likely preferred them to *chultunes* that had a higher potential for failure during the driest months of the year. There are no documented wells at Yula.

Coastal District: The Coastal Sites

Overview

While other districts in Wilson's (1980) physiographic classification contain significant variability, the Coastal District is more homogeneous with respect to the variables I determined to be most relevant for this study. For this reason, a general overview of the district is presented instead of localized variations discussed on a site-by-site basis.

Wilson's Coastal District covers approximately 8,209 square kilometers of coastal lowlands stretching from the modern day city of Campeche on the southwestern Gulf Coast to Tulum on the Caribbean. The district extends inland 5.5 kilometers near Tulum to approximately 23.5 kilometers along the northwestern coast (Figure 5.21). During fieldwork, five sites were surveyed in the Coastal District. The sites surveyed were Isla Cerritos, Tulum, Xcambo, Xcaret, Xelha, and one, Noh Ichmul, 1.5 kilometers west of Chetumal Bay. Wilson (1980) characterized this district as having beach ridges, rocky coastlines, partly flooded areas containing short streams, barrier ridges, lagoons, and islands, elevated Pleistocene shorelines, low cliffs, large and small embayments and swamps.

While Wilson discussed ground water, he did not place great emphasis on depth to aquifer nor consider accessibility

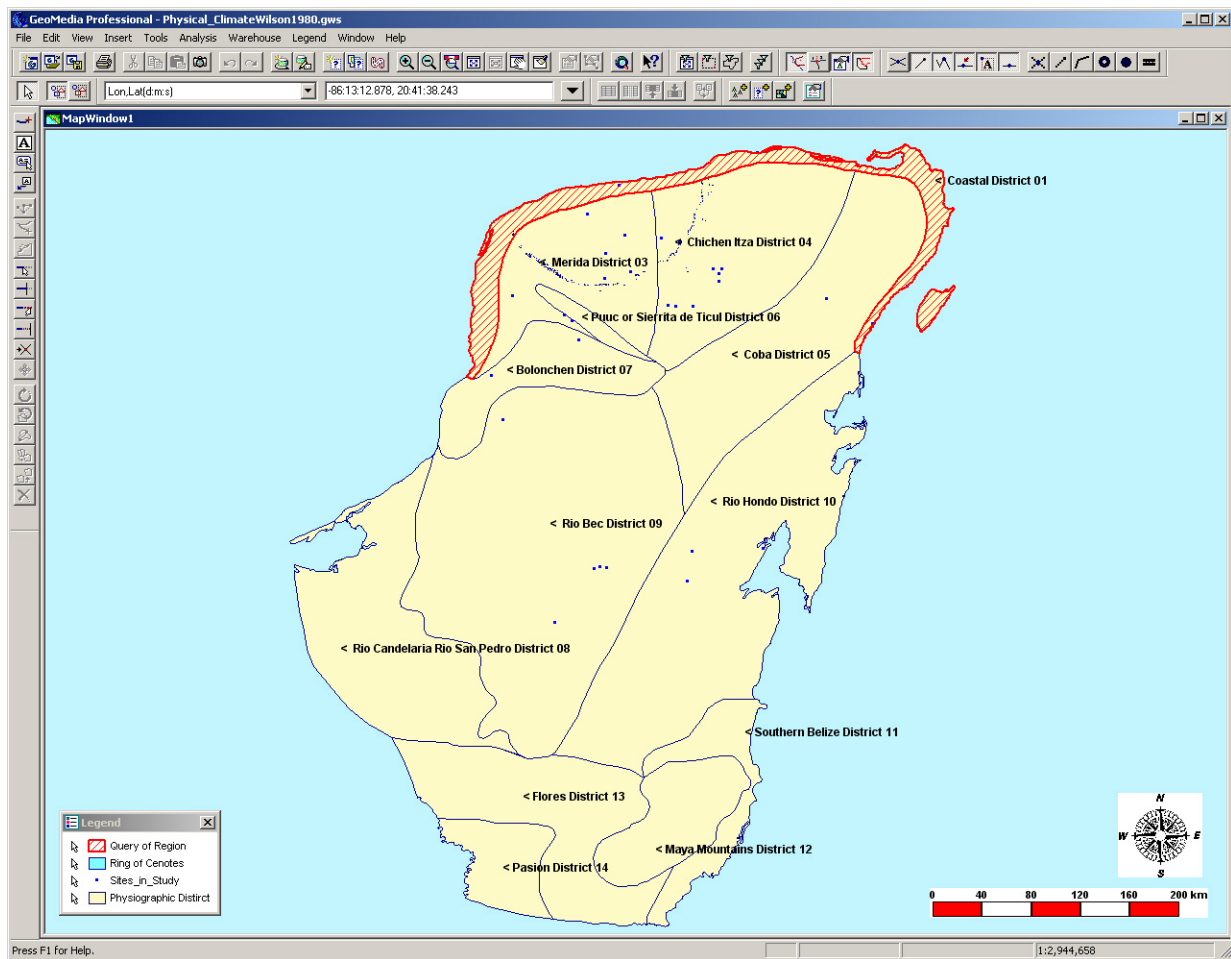


Figure 5.21 Wilson's Coastal District in the project GIS.

of the phreatic a defining characteristic in his physiographic typology. In most areas of the Yucatán, subterranean fresh water flows from central and southern sections toward the Coastal District. As this paper demonstrates, depth to phreatic significantly impacted options available to the Maya and the resultant hydrological regimes observed during field study. Depths of the aquifer throughout the Coastal District including eastern and southeastern portions of the Rio Hondo District

from Tulum to Chetumal average less than five meters (Dirección General de Administración y Control de Sistemas Hidrológicos Dirección de Aguas Subterráneas 1988, 1989a, b). In many areas, fresh water lies a few centimeters below the surface or boils up in springs known as *ojos de agua* (eyes of water) or sea estavellas offshore in the Gulf and Caribbean waters. Sea estavellas are connected to subterranean freshwater rivers flowing through inland *cenotes*, fractures, tunnels, tubes, and passages toward the sea. These features are now the focus of INAH underwater archaeologists and marine biologists from Texas Agricultural and Mechanical University (Skiles 2003). I expected to find few examples of active adaptive strategies and a preponderance of passive use of natural resources in this district. In some instances no evidence of terrestrial sources of fresh water were noted. The most notable example of a site having no evidence of water sources is Isla Cerritos.

Isla Cerritos

Today, the shoreline of Isla Cerritos, a fourth-ranked site (Garza and Kurjack 1980), is located 0.53 kilometers offshore on the northern Gulf Coast approximately 5.53 kilometers west northwest of the modern town of San Felipe, Yucatan, Mexico at 16Q 366980mE, 2385124mN UTM, 21° 33' 50.613" North, 88° 17' 05.009" West (Figure 5.22). For a detailed

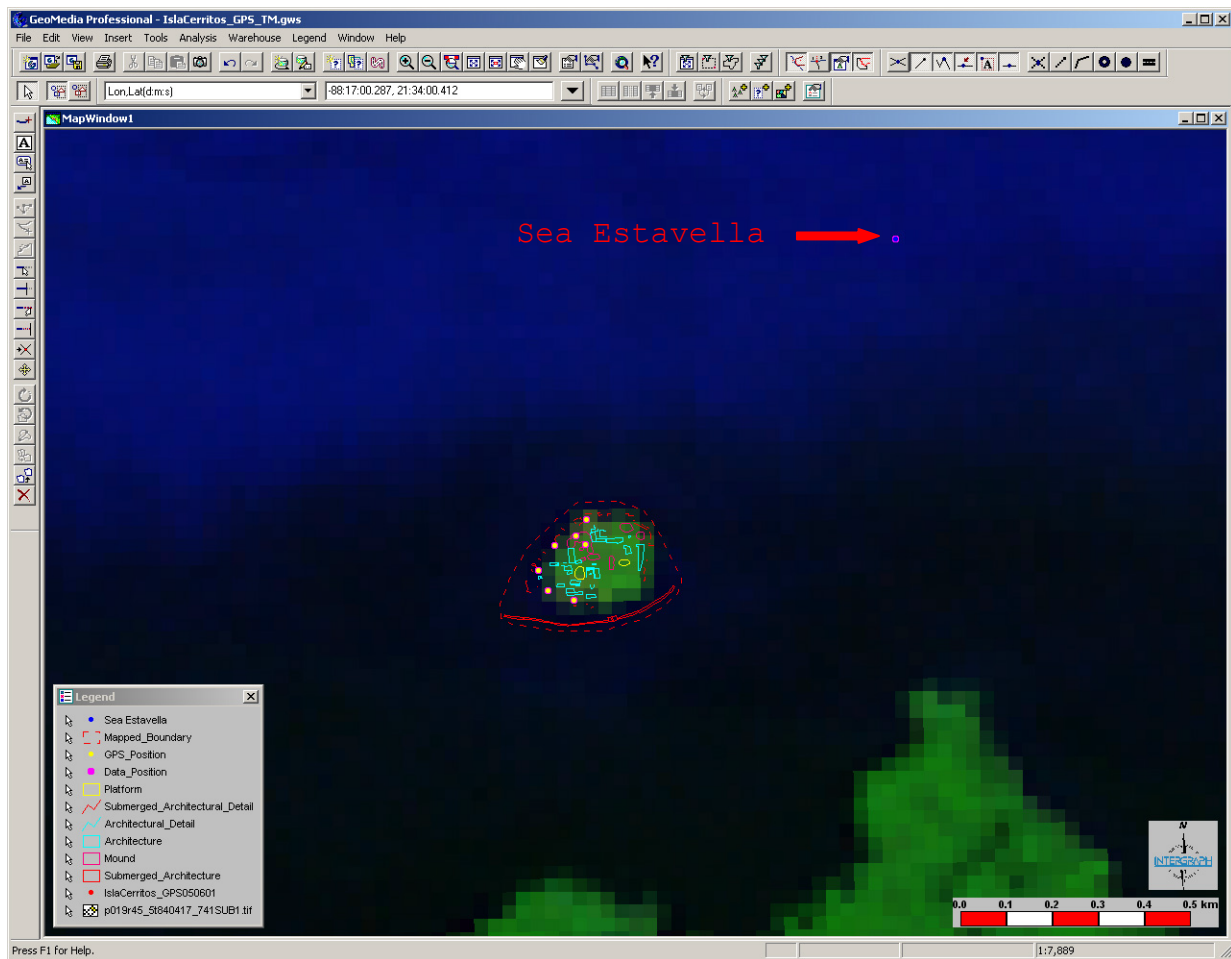


Figure 5.22 Map of Isla Cerritos in project GIS. Landsat TM courtesy of NASA.

description and history of research at the site see (Andrews et al. 1986; Eaton 1978). During its apogee, exposed portions of the island site were significantly larger. No sources of water or notable depressions like *aguadas* that might have captured rainwater exist on the island. Considering its location, evidence of hydrological management features might have been covered up by the frequent hurricanes moving across the area. Several sea estavellas occur near the island. The modern day

fishermen of San Felipe know the location of these subsurface springs.

If the ancient inhabitants did collect water from sea estavellas, they most likely accomplished this task during low tide when the subsurface springs located between the island and the coastline were exposed by receding tides. Friar Diego de Landa (1978) noted that he personally collected "sweet water" from springs rising in the sea at ebb tide. Diaz del Castillo (1956) mentioned filling water casks from springs along the coast as well. *Petens*, are springs that surface near the coast, often in shallow estuaries. A large *peten* is located near the site of Paseo de Cerros on the Yucatán coast just over two kilometers south of Isla Cerritos (Andrews: personal communication 2001). This feature could have provided water to the inhabitants as well. No efforts were made to locate the *peten* during fieldwork.

The ancient inhabitants most likely collected water by excavating shallow depressions to collect rainwater or extract fresh water from perched lenses. Evidence of this strategy would be extremely difficult to detect in the archaeological record, however, ethnographic examples of this strategy exist. Heather McKillop (personal communication 2003) noted that local inhabitants in southern coastal Belize excavate small pan-

shaped depressions in some areas to collect fresh water from the perched aquifer located a few centimeters below the ground surface.

Xcambo

Unlike Isla Cerritos, survey of Xcambo revealed seven springs or *ojos de agua* that would have supplied the ancient inhabitants of the site with fresh water. One spring required some investment of energy to excavate through a thick layer of caprock. This feature was ultimately classified as a well. Xcambo is located approximately 2.4 kilometers inland and 45.5 kilometers northeast of Merida, Yucatán at 16Q 255828mE, 2358703mN UTM, 21° 18' 49.748" North, 89° 21' 13.959" West. The fourth-ranked site (Garza and Kurjack 1980) covering approximately 0.096 square kilometers is bounded by an estuary to the north and grass flats to the south (Figure 5.23).

The Xcambo 1996 informe, documented a single *chultun* in the site core (Sierra Sosa et al. 1996). Considering the location of the site within a physiological zone where phreatic depth averages less than one meter, it is doubtful that a functional *chultun* could have been constructed or would have been employed by the inhabitants as an adaptive strategy to secure water. Furthermore, no evidence of a bell or amorphous shaped chamber exists and a community of fish living in the

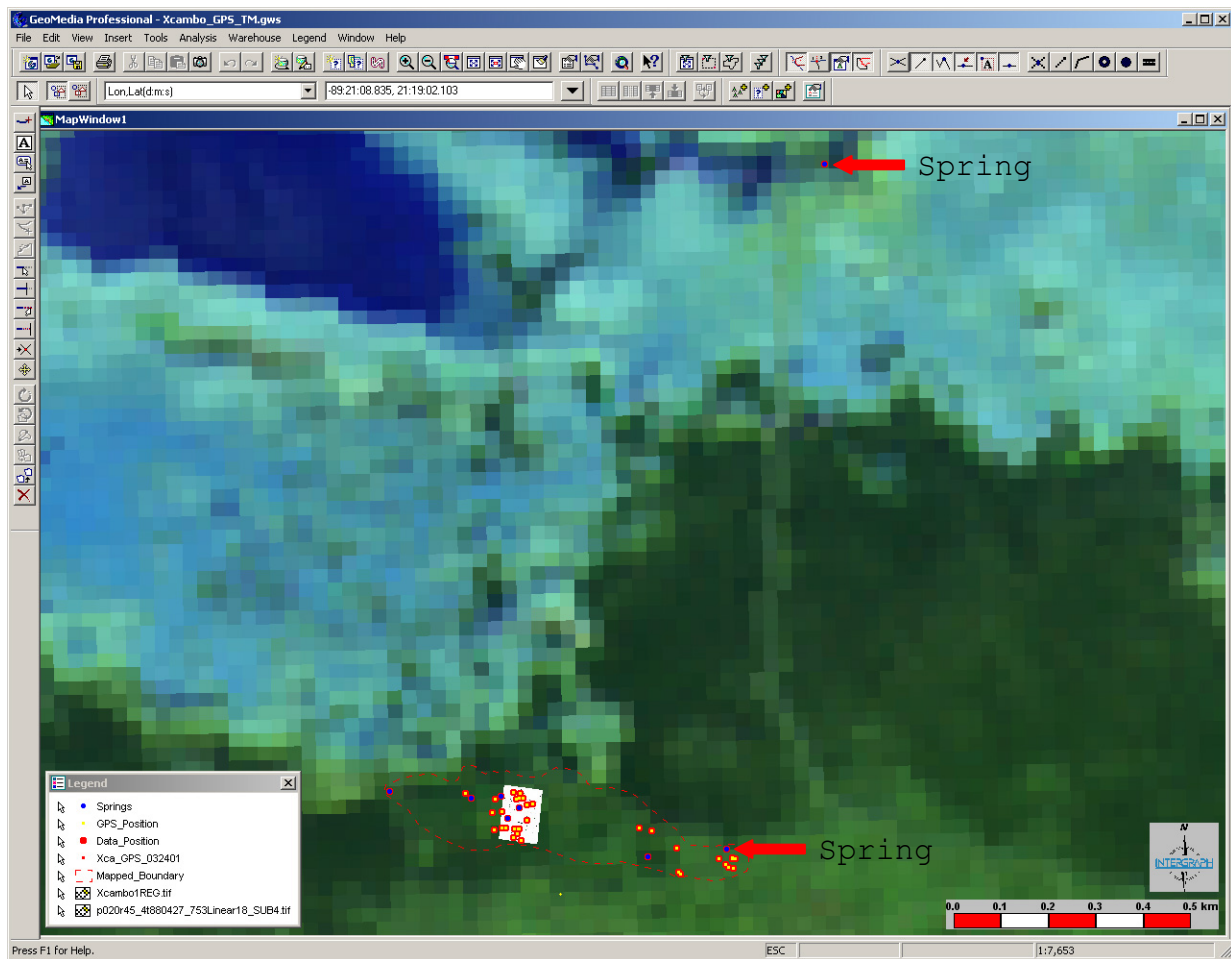


Figure 5.23 Map of Xcambo in the project GIS, adapted from Sierra Sosa et al. (1996). Landsat TM courtesy of NASA.

feature suggests the water is regularly recharged with freshwater flowing from a subterranean source. The feature was recorded as a spring. During survey, several inconsistencies between building depicted on the site map and the corresponding architecture were noted. Several additional years of work were accomplished after publication of the 1996 map but were not available for review. Therefore I am unaware of any subsequent corrections to the map, new discoveries, or conclusions beyond

those advanced in the initial report. The presence of several springs at Xcambo indicates that the ancient inhabitants were not required to invest substantial amounts of energy into constructed hydrological management systems. However, the effects of hurricanes in the area would have been catastrophic. For a description of the site and preliminary discussion of work completed at Xcambo see (Sierra Sosa et al. 1996).

Xcaret

Xcaret is a fourth-ranked site situated on the Caribbean Coast approximately 70 kilometers south of Cancun and 17.5 kilometers northwest Isla Cozumel Island at 16Q 487552mE, 2275563mN UTM, 20° 34' 44.499" North, 87° 07' 09.991" West. The known boundaries of the fourth-ranked site (Garza and Kurjack 1980) delimit an area covering 0.74 square kilometers. Survey beyond existing mapped boundaries identified archaeological remains suggesting that the settlement was considerably larger than the mapped area. The central precinct consists of five or six clusters of monumental architecture, depending on whether or not Group F and G are considered as solitary settlement units or a single one cluster. Dispersed small clusters of unvaulted structures as well as solitary buildings surround major architectural groups (Figure 5.24). Like other coastal

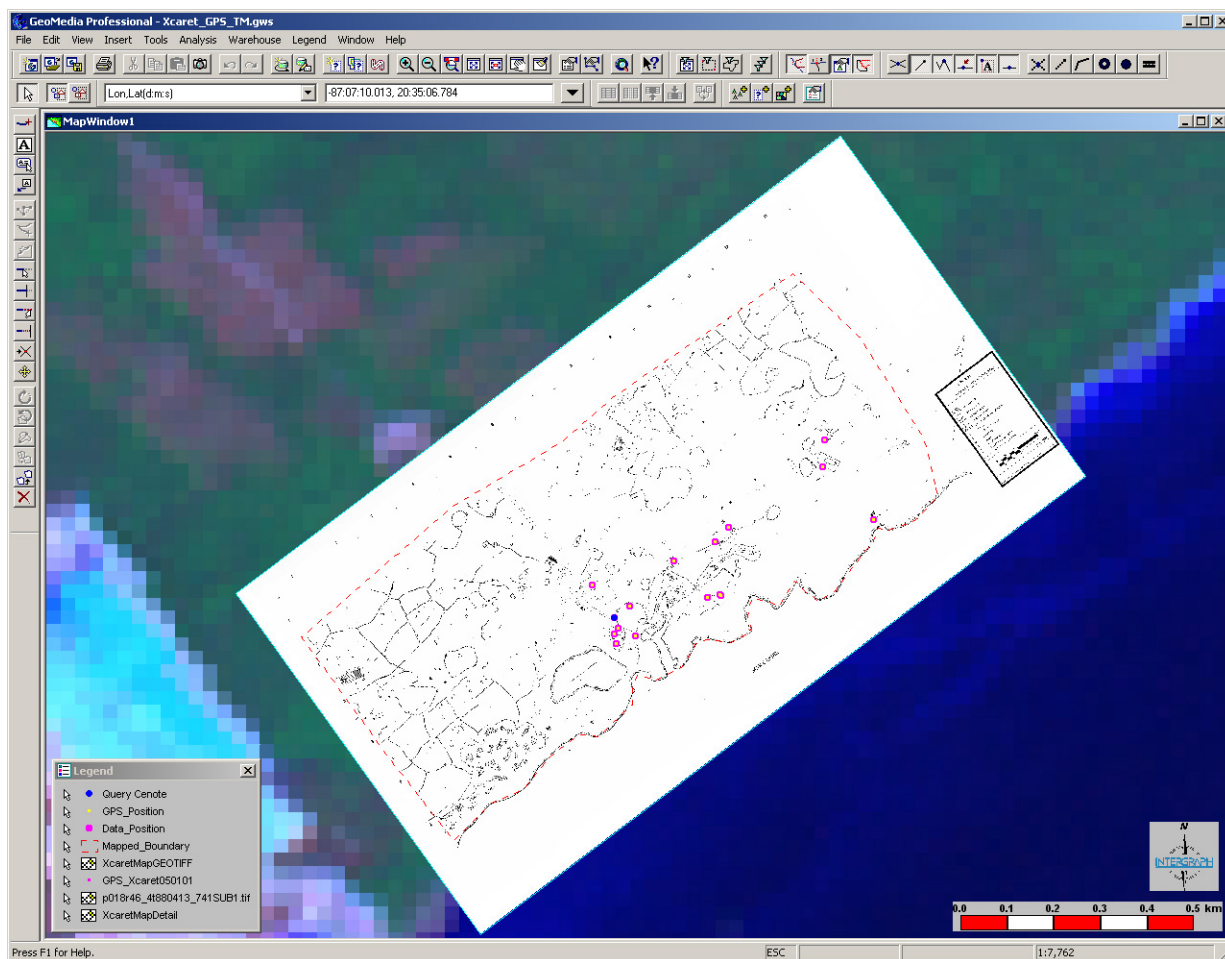


Figure 5.24 Map of Xcaret in the project GIS, adapted from Con Uribe (1986). Landsat TM courtesy of NASA.

sites in northern Quintana Roo, Xcaret enjoyed a thriving Post Classic occupation. Coastal sites were described by Lothrop and Andrews (Andrews IV and Andrews 1975; Andrews IV and Andrews V 1975; Lothrop 1924). In 1986, several years after a version of the map of Xcaret was completed by Andrews IV and Andrews (1975), INAH implemented a major project under the direction of INAH archaeologist Maria Jose Con to accomplish consolidation



Figure 5.25 *Cenote or ojo de agua at Xcaret.*

and restoration and complete the Xcaret map. Work at the site continues today. For a comprehensive account of research at Xcaret as well as other coastal sites see (Andrews IV and Andrews V 1975; Con 1986, 1987, 1989, 1991a, b, 1992, 1995; Lothrop 1924; Maldonado Cardenas 1987).

A single undisturbed *cenote* or *ojo de agua* was observed (Figure 5.25). The complex subterranean network of channels and passageways that supplied fresh water to the ancient inhabitants of Xcaret was disturbed in recent times to

accommodate a modern day theme park. Now, water is pumped through the altered network creating currents to enable divers to travel between separate chambers. Evidence of the hydrological regime at Xcaret is consistent with a typical adaptive strategy indicated at other sites in the Coastal District.

Xelha

Xelha is situated along the coast 41.5 kilometers south of Xcaret at 16Q 461672mE, 2246835mN UTM, 20° 19' 08.706" North, 87° 22' 01.734" West. The cultural landscape at Xcaret is similar to other sites in the district. The 1980 - 1982 map of Xelha (Perez Alvarez and Cobos 1982) was incorporated into the project GIS. This map covers an area of 2.2 square kilometers. Xelha contains three principal groups with monumental architecture. By contrast to the fairly even distribution of solitary buildings and clusters of unvaulted architecture in the peripheral zone at Xcaret, the dearth of architectural remains in the periphery of Xelha suggests areas beyond the central precinct were sparsely populated. The site contains one *cenote* on the northern edge of Group C that might have provided water to the ancient inhabitants (Figure 5.26). The water level in this *cenote* measured 3.5 meters below the ground surface. The water in the *cenote*, although brackish, is potable. Group C

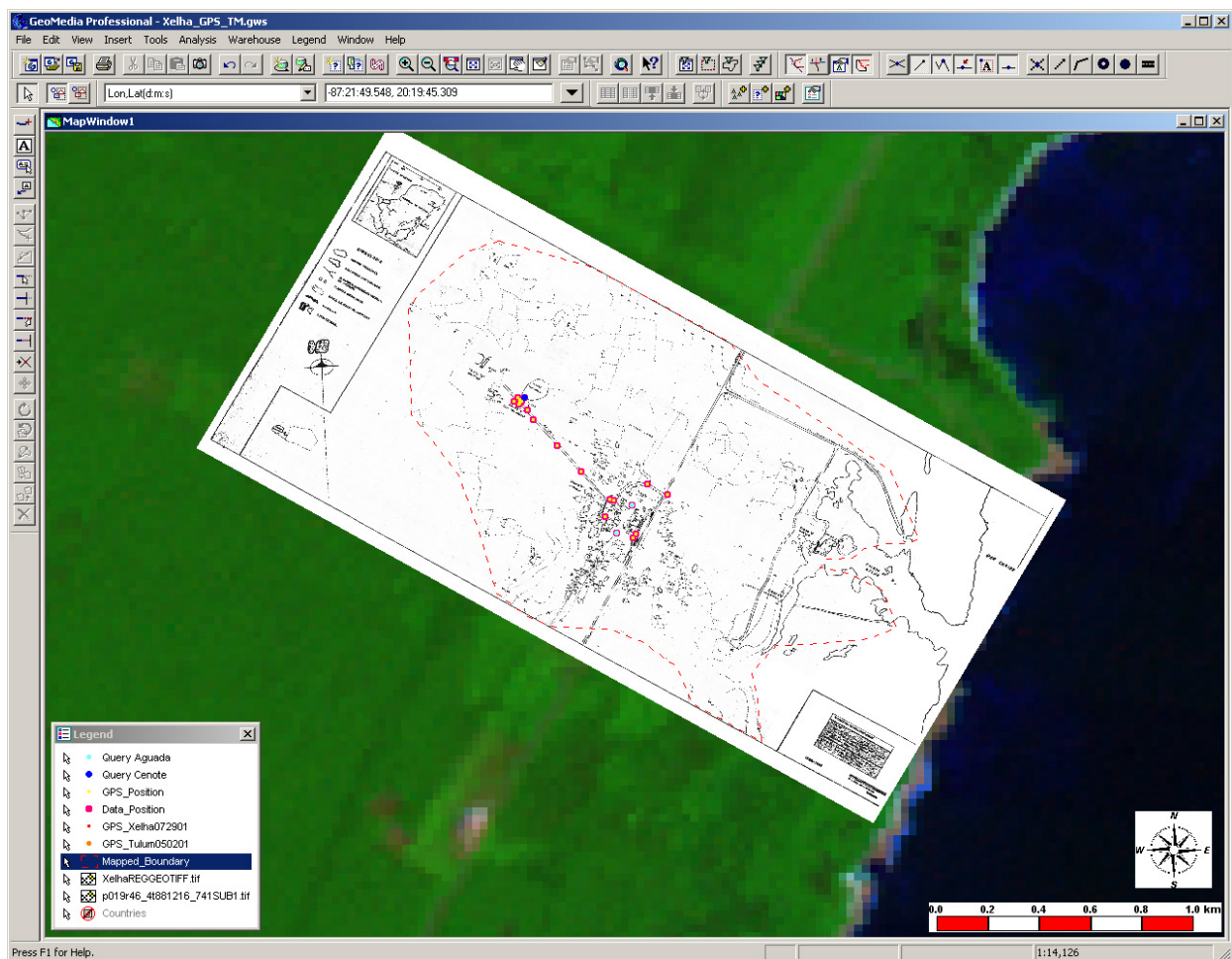


Figure 5.26 Map of Xelha in the project GIS, adapted from Perez Alvarez and Cobos (1982). Landsat TM courtesy of NASA.

is linked by a 650-meter long causeway to Group B, the largest cluster at Xelha. No water features were found in any of the architectural groups.

A depression covering approximately 3,270 square meters is located between two plazas in Group B. The deepest portion of the depression near the center is 1.75 meters below the rim. Architectural remains surround the depression, but no evidence

of structures was found inside the depression suggesting the inhabitants avoided the feature. Today, grasses but no trees grow in the depression suggesting the soil type or quality and drainage are unsuitable for growth of trees. The depression appears to have been a source of water for the inhabitants of the surrounding area. Xelha might have contained several ojos de agua during its apogee as well.

Tulum

The walled site of Tulum is 13 kilometers south of Xelha. Tulum is a second-ranked site (Garza and Kurjack 1980) situated at 16Q 455187mE, 2235279mN UTM, 20° 12' 52.283" North, 87° 25' 44.344" West. The wall at Tulum encloses the central precinct and architectural center of mass. The walled portion, an area measuring 0.072 square kilometers, was mapped by Lothrop of the Carnegie Institution of Washington, D.C. (Lothrop 1924).

In 1518 Spanish explorers under the charge of Juan de Grijalva, the nephew of Diego de Velázquez governor of Cuba, first sighted and described a city as large as Seville, Spain (Diaz 1972). Many scholars believe the Spaniards were describing Tulum. If the author of this account was referring to Tulum, the passage provides a clue to the true size of the site. Velazquez Valadez (1976) mapped portions of the site

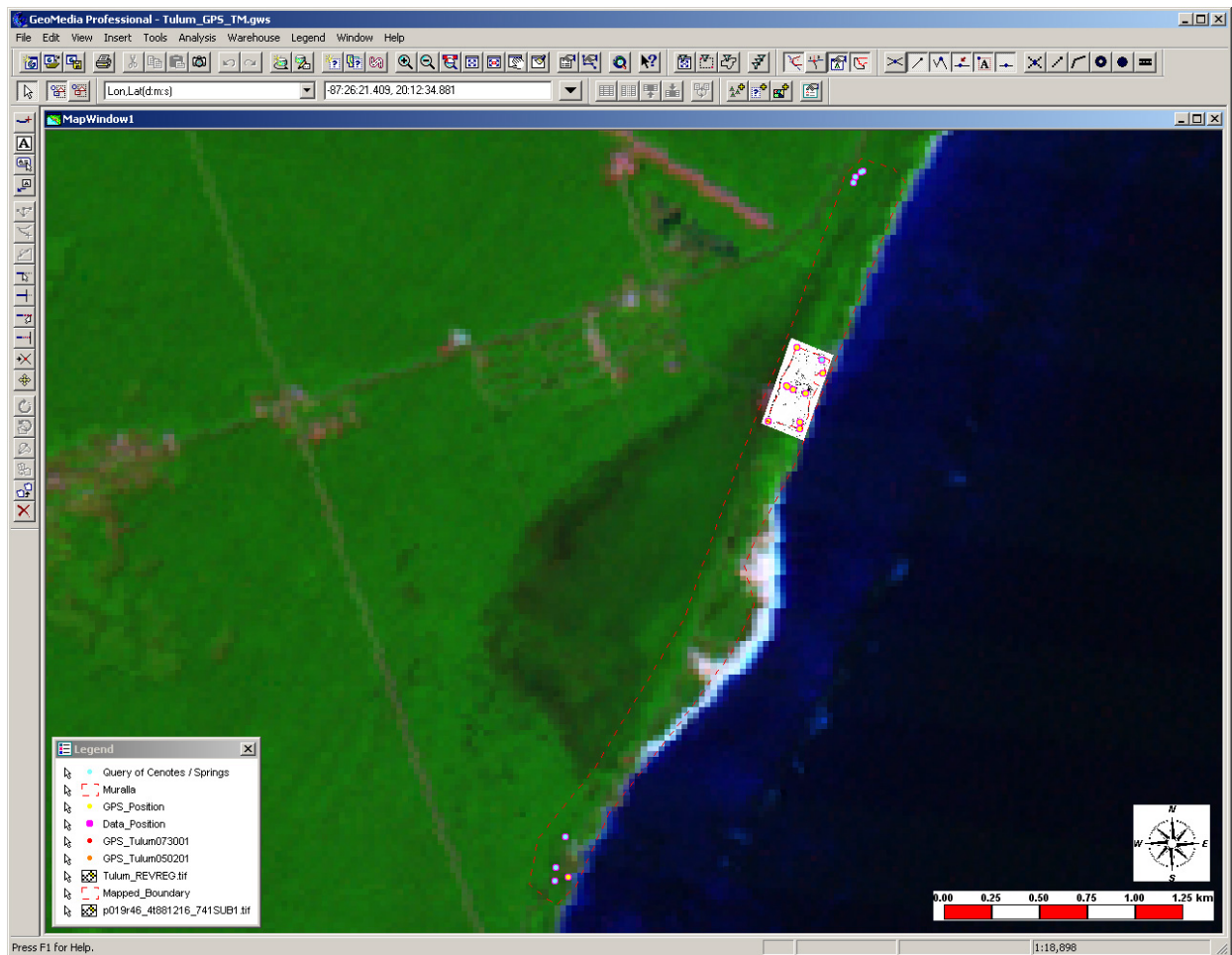


Figure 5.27 Map of Tulum in the project GIS. Landsat TM courtesy of NASA.

extending approximately one kilometer north and 2.7 kilometers south of the walled central precinct covering an area of 1.14 square kilometers and mentioned finding *cenotes* and *aguadas* in the survey zone (Figure 5.27). The vaulted architecture at Tulum resembles structures at Xelha and Xcaret.

Stephens (1988) provided the first detailed historical description of Tulum including several principle structures,

the wall, and documented a stairway leading from a structure to a "brackish" *cenote*. Holmes (1895) visited and sketched several panoramic views of the site and remarked about similarities between Tulum and Chichén Itzá. Under the direction of Sylvanus Morley, the Carnegie Institution of Washington completed the first scientific investigations of the site between 1916 and 1922. Since the Carnegie, INAH has completed several field seasons at the site, see (Barrera Rubio 1980).

Lothrop (1924) published the results of Carnegie work at the site and described in detail the *Cenote House* and the associated *cenote* recorded by Stephens 60 years earlier (Figure 5.28). The *cenote* is a small example of the larger type 3 *cenotes* (Roys 1939) mentioned elsewhere in this paper. Lothrop described the water in the *cenote* as "a small pool of brackish water, foul with bat-dung, but still drinkable" (1924:109).

Lothrop's comment about the quality of water in the *cenote* points out an essential consideration regarding this research. We, as members of western society, assume the Maya sought water that was both crystal clear and free of impurities, like the water drawn from faucets. During field survey, I occasionally observed workers, and at times, was compelled to take water from the substance of this study including *aguadas*, *cenotes*, lakes, *ojos de agua*, sacred querns, *haltunes*, wells, and those



Figure 5.28 *Cenote* below the *Cenote House* at Tulum.

dark pools of water inside caves. In every instance, the water I drank did not fit western notions about where potable water should come from, how it should look and taste, or its symbolic nature. Both water jars and human skeletal remains were observed in the cave at X-Kukican, (Cottier 1967; Nielson and Sheldon 1971). The Maya sought the water they needed to survive in brackish pools, *sartenejas*, springs, petens, ponds, lakes, rivers, and dark caves.

A passage in the *Chilam Balam of Chumayel* recounted events taking place during an epic journey of the Itzá.

"Then they arrived at Kikil, where they contracted dysentery. Kikil was its name here, so they said. Then they arrived at Panabhaa, where they dug for water... Then they went to Ticul, Zacluum-cheén (Sacalum, Tixtohil-cheén Xtohil), where they recovered their health" (Roys 1931).

The travelers went on to establish Chichén Itzá as their capital city. Kikil is a place located four kilometers north of Tizimin. The *Mayan* word *k'ik'* alone means blood or bloody and *il* means affliction or misfortune (Barrera-Vasquez 2001). Therefore *k'ik'il* translates to *cruento* in *Spanish* meaning bloody or cruel misfortune (bleeding dysentery). The Panabhaa in Roys' is most likely panaba in *Mayan* (Barrera Vasquez 2001). The toponymic translation of *panaba'* is "place where water was excavated" and the word *panab* means a shallow basin of stone or wood, a vessel used by the Maya to wash clothing. The modern town of Panaba is located 27.5 kilometers south of Isla Cerritos, a site believed to be a port of trade for Chichén Itzá, and north of Tizimin in the province identified by Roys as Kupul.

Roys' translation of the narrative alludes to the problems associated with the water in karstic environments such as the Yucatán and method the inhabitants employed to procure water. Goodner (1933) reported that a large portion of deaths in

Yucatán were attributable to diarrhea, enteritis, or dysentery. During 1924 and 1925 40.2 percent of all deaths in Merida, Yucatán were attributed to the three ailments mentioned above. Among children the rate was 58 percent. Goodner attributed the high incidence of deaths from intestinal infections to pathogens in the water supply introduced by the inhabitants' inability to keep human waste and other pollutants from entering the aquifer. In many cases surface runoff drained into *cenotes* situated on or near central plazas. It is safe to assume that, except for industrial pollutants, the problems Goodner observed in traditional rural Maya villages in 1929 mirror the ancient past.

A significant proportion of field survey was conducted beyond the walled central precinct at Tulum. During the field survey six water features were noted outside the wall (Figure 5.29). Although the local inhabitants labeled all of these features *cenotes*, their size and form more closely resemble springs or *ojos de agua* and *aguadas*; none resemble the *cenote* observed at Xelha. One feature located 4.5 kilometers south of Tulum closely resembled the Xelha *cenote* but had no associated archaeological remains. Clearly, the hydrological regime at Tulum fits the Coastal District strategy. Like Xcambo, there is one feature labeled a *chultun* inside the walled central



Figure 5.29 Feature at Tulum labeled a *cenote* found near an architectural group located 2.3 kilometers south of the wall.

precinct. Sediment prevented confirmation as to whether or not the circular feature was a storage chamber. Thus the term *chultun* might not accurately describe the feature.

Noh Ichmul

Noh Ichmul is a third-ranked site situated 19.3 kilometers north northeast of the modern day city of Chetumal, Quintana Roo and 1.5 kilometers west of Chetumal Bay. Most of the

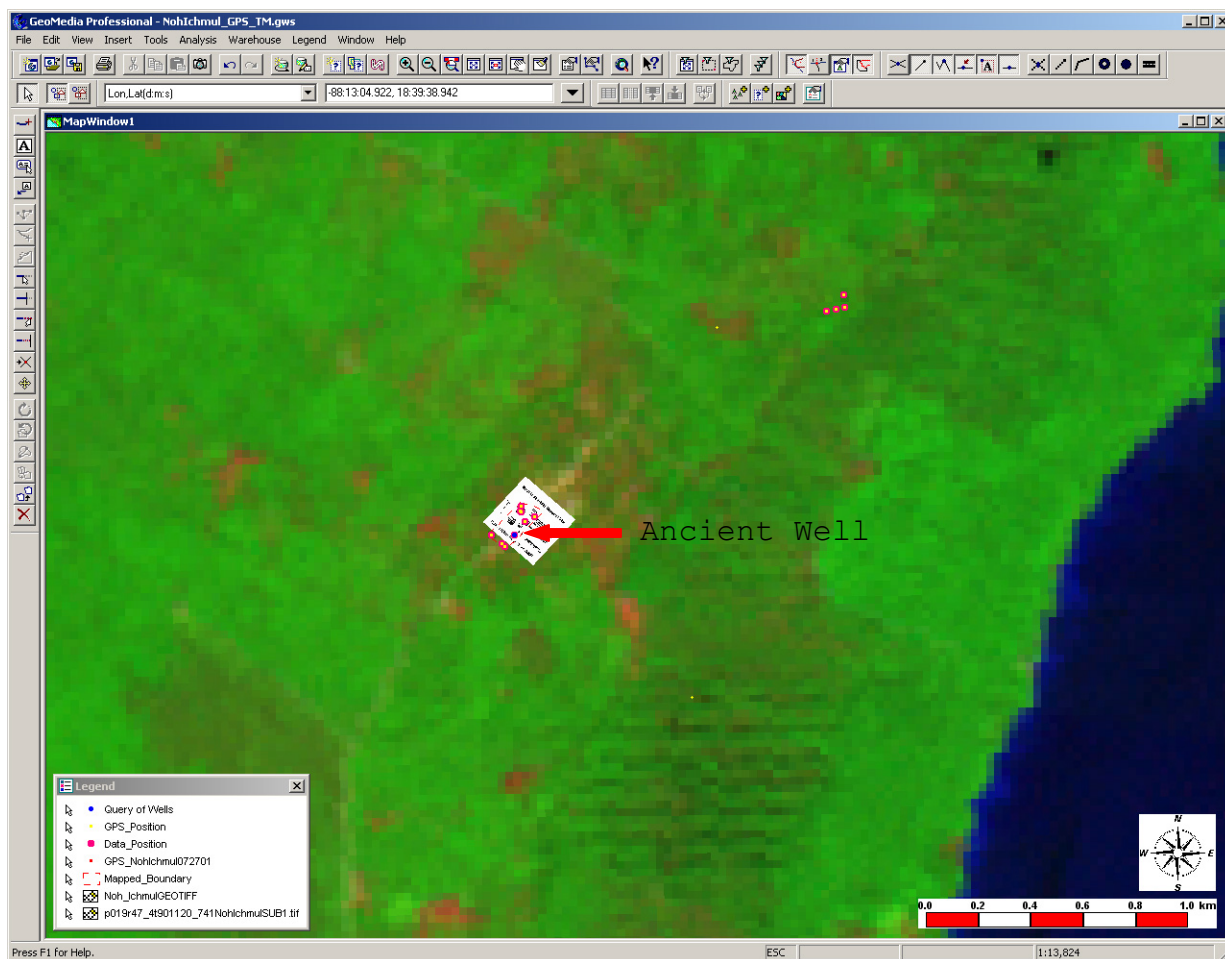


Figure 5.30 Map of Noh Ichmul in the project GIS. Landsat TM courtesy of NASA.

archaeological site was destroyed during construction of the modern town of Luis Echeverria Alvarez. A cluster of five mounds located off the central plaza in the center of Luis Echeverria Alvarez is all that remains of the ancient site (Figure 5.30). Finding no apparent source of water, local residents were surveyed for information regarding modern-day sources of water. Nearby residents revealed the locations of



Figure 5.31 Ancient well shaft at Noh Ichmul, Quintana Roo.

two wells. One of the features was modern. The other, located 60 meters south of the center of the mound cluster, appeared to be ancient in origin (Figure 5.31). The well resembled others surveyed at Acanceh, Aké, and Dzibilchaltún and penetrated a subterranean chamber containing water. At the time of survey, the water level was four meters below the ground surface. The environmental profile at the site, including a perched freshwater lens, caverns and relative ease of access to the

phreatic permitted excavation of wells as an adaptive option. Considering these conditions, finding a well at Noh Ichmul is predictable.

Coba District

Coba

The site of Coba is situated in the eastern portion of the peninsula approximately 50 kilometers inland, near a group of lakes associated with the geological region referred to as the Holbox fracture zone (Figure 5.32). The Holbox is a zone of linear depressions and swales that follow and underlying system of horst and graben features within horizontally-bedded Tertiary carbonates (Tulaczyk et al. 1993; Weidie 1982, 1985). Coba is located at 16Q 423659mE, 2265868mN UTM, 20° 29' 23.713" North, 87° 43' 55.467" West in the Coba (Wilson 1980). The district is primarily a tropical savanna consisting of a karst plain with small depressions and hills, large lakes, and linear depressions (Figure 5.33). Rainfall in the district averages between 1000 and 2000 millimeters annually. Coba is situated among five large lakes and in the portion of the district that experiences the highest annual rainfall (INEGI 2001c). Access to sufficient quantities of water for human consumption most likely was not a problem for inhabitants living near the

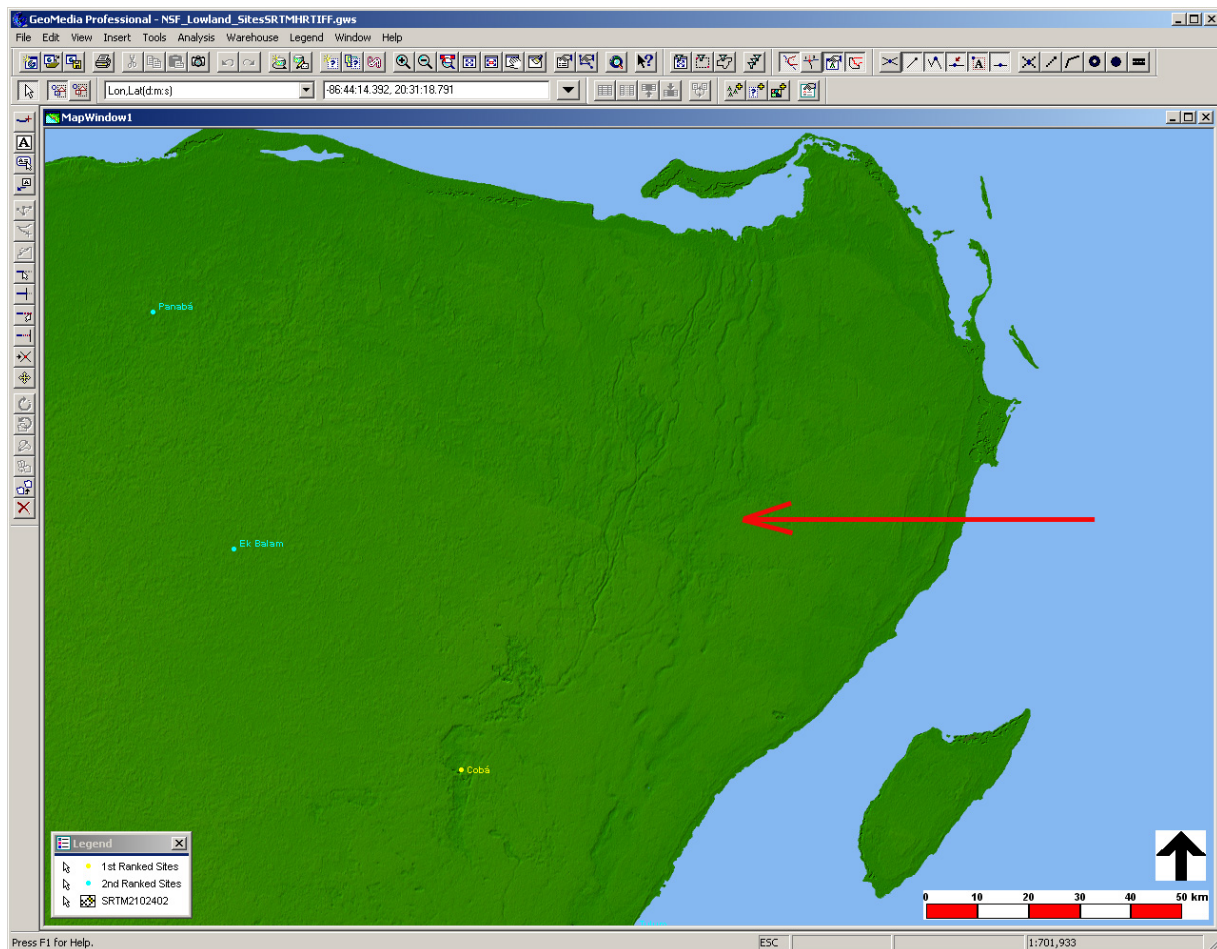


Figure 5.32 SRTM image showing depressions in the Holbox Fracture Zone area (red pointer). Coba is noted in yellow to the southwest. Shuttle Radar Topography Mission Imagery courtesy of NASA.

lakeshore. The inhabitants settled farther from the lakes were compelled to adapt differently. Measured depths to the phreatic in the Coba area average between 15 and 20 meters (Dirección General de Administración y Control de Sistemas Hidrológicos Dirección de Aguas Subterráneas 1989a).

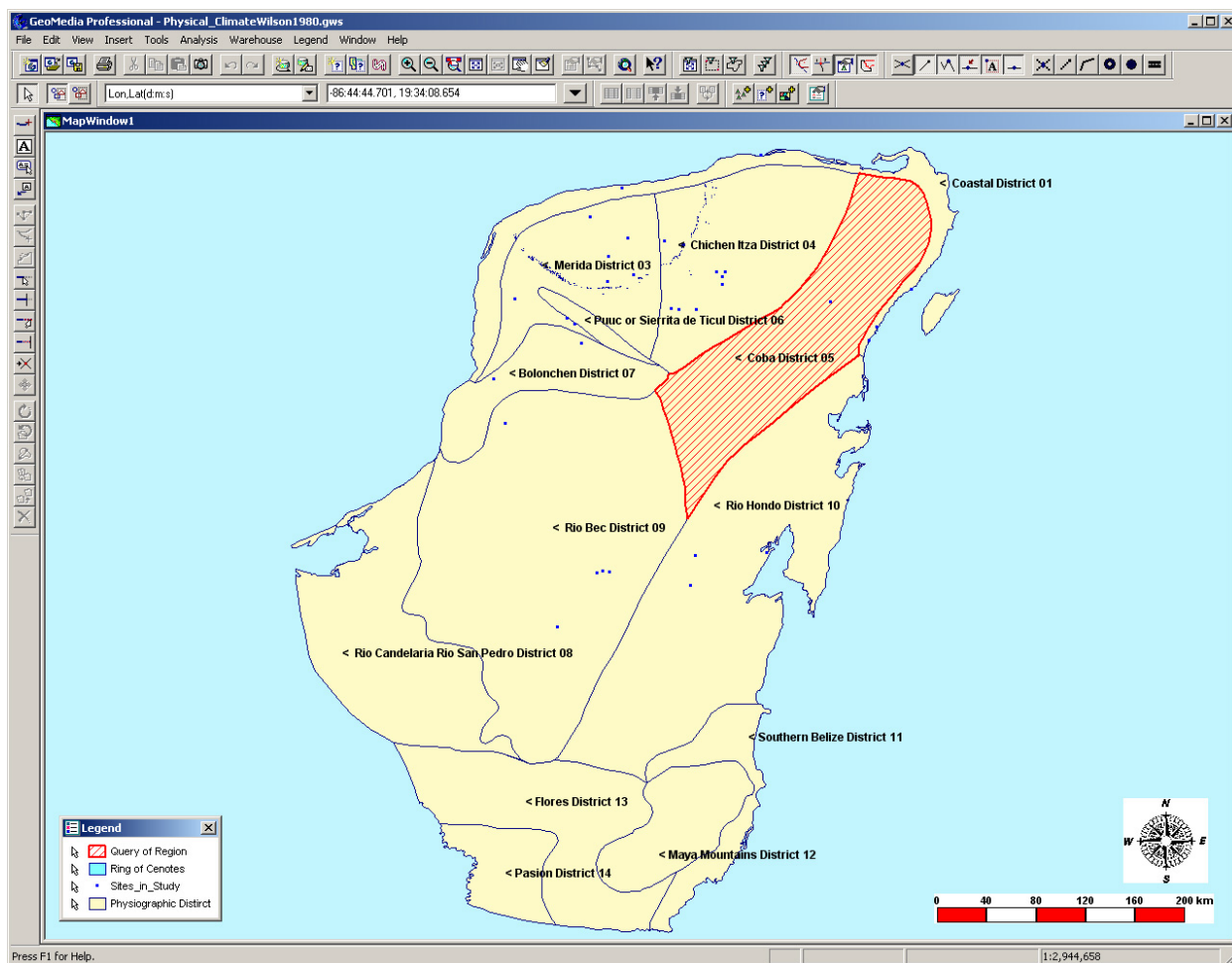


Figure 5.33 Wilson's Coba District in the project GIS.

Stephens (1988) provided the first modern account of Coba. Stephens commented briefly on a quotation taken from the records of the curacy of Chemax about the site and local speculation naming Chichén Itzá as the ultimate destination of a calzada or causeway leading from the structure known as the Monjas Stephens (1988). Thompson, Pollock and Charlott (1932) published an early survey report and map describing the

arrangement of architectural groups, structures, and monuments at Coba. During the 1970s, Navarrete, Con Uribe and Martinez Muriel (1979) completed survey and published a map of features situated along Causeway 3. Folan (1978) and Folan et al. (1977) investigated causeways and produced a map of the site.

Under the direction of the Coba Archaeological Project, Garduño Arqueta (1979b) produced maps of perpendicular transects of the site providing detail about previously unmapped architectural groups. Benavides Castillo (1981) studied the system of causeways and their social implications. Robles Castellanos (1990) established a ceramic sequence for the site. Robles provided a copy of an unpublished map covering a portion of the site. I integrated Robles' map into the project GIS with others produced by Thompson, Pollock and Charlot (1932); Navarrete, Con Uribe and Martinez Muriel (1979); Folan et al. (1977); and Garduño Arqueta (1979a, b). Today, large areas containing architectural remains and associated features beyond the ceremonial precinct have not been surveyed or mapped. An ongoing INAH project including consolidation and restoration of various structures at Coba is under the direction of Dr. Alejandro Martinez Muriel and archaeologist Maria Jose Con (2000).

The publications cited above represent a fraction of the literature on the subject of Coba. Discussing this body of work is beyond the scope of this paper. For a thorough account see (Benavides C. 1981; Garduño Arqueta 1979a; Martinez Muriel and Con Uribe 2000; Navarrette, Con Uribe and Martinez Muriel 1979; Robles Castellanos 1990). In an effort to establish an all-inclusive map of Coba, all the available maps were georeferenced and plotted in the project GIS. A boundary based on the maximum extent of settlement covered by the maps was drawn in the GIS (Figure 5.34). The area covers approximately 30 square kilometers. While tracing a causeway northwest of the central precinct, continuous settlement units that were not recorded on existing maps were encountered prompting the assumption that calculations based upon known maps are highly conservative estimates. Most likely the actual figure exceeds my calculations by as much as 20 additional square kilometers.

During fieldwork, eight *aguadas*, one *cenote*, two *chultunes*, two caves, four *sartenejas*, multiple solution shafts known to the local inhabitants as *aktuns*, and three wells were surveyed and recorded. This sample of *aguadas* represents a small percentage of the numerous walled small *aguadas* observed in the field. I labeled these small water features *aguaditas*. Portions of the shorelines and margins of five lakes (Coba,

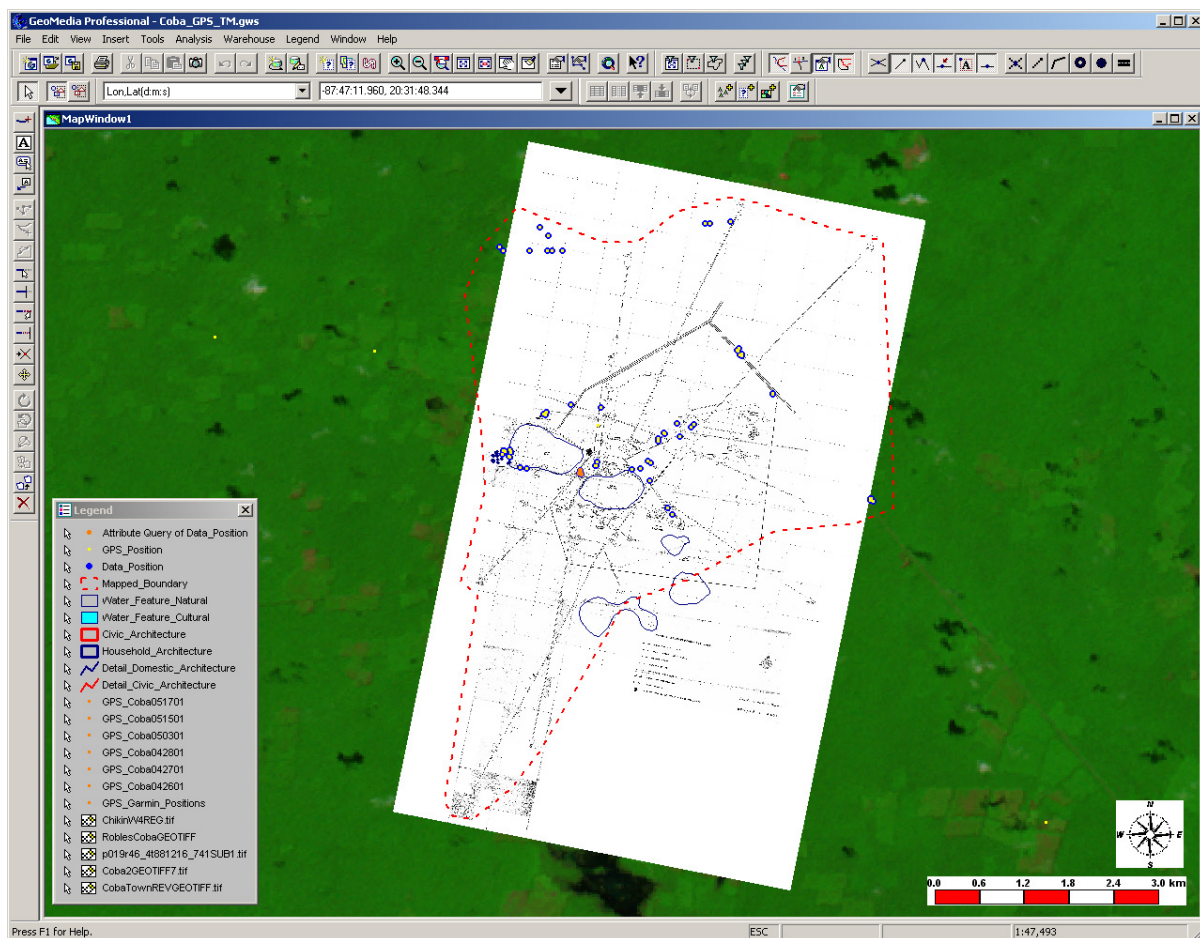


Figure 5.34 Robles map of Coba in the project GIS. Red dashed-line represents mapped boundary. Landsat TM courtesy of NASA.

Chacluk, Macanxoc, Sacalpuc, and Xkanha) were reconnoitered. Clearly, the five large and other small lakes in the area would have been reliable sources of water for the ancient inhabitants of Coba. The largest architectural group, the Coba Group is situated adjacent to Lake Coba and Lake Macanxoc.

One group situated on the southwestern shore of Lake Coba in an area known as Chikin contains the remains of vaulted



Figure 5.35 Mound and stone alignment at Lake Coba.

structures. Figure 5.35 illustrates one of several ancient walkways found that lead from the shoreline into the water and a rectangular dock-like feature constructed with large stones adjacent to a mound on the southern shore of Lake Coba. A surface collection from one area near a walkway revealed a cluster of obsidian debitage and several broken and worn blades. The context suggests the inhabitants might have been processing fish from the lake or other consumables. The Chikin group is similar to other clusters of architecture containing

evidence of vaulted structures located along the shores of Lake Coba and Lake Macanxoc. Although, there is clear evidence of cultural activities in the lakeshore context, evidence such as raised agricultural plots, irrigation channels or diversion features, to suggest the Maya were engaged in large-scale water management activities does not remain today. The environmental profile at Coba predicts a combination of passive and active adaptive strategies including *aguadas*, *chultunes*, and wells. Several large groups containing monumental architecture, Chumuc Mull, Nohoch Mull and Uxulbe Uucare, are not located near Coba's lakes. Several *aguadas* and large *sascaberas* were found near these groups. Portions of the *sascaberas* are excavated to bedrock and might have functioned as seasonal reservoirs. One *aguada* is located adjacent to the western edge of the platform that supports the Nohoch Mull. Water in the center of the *aguada* measured five meters deep. Modification of depressions or *aguadas* appears to be an option the Maya of Coba employed when transportation of water over distances approaching one kilometer would have required substantial effort. This medium-sized reservoir had steps cut into bedrock leading from the platform into *aguada* (Figure 5.36).

Beyond the central precinct and more distant groups, domestic groups having no vaulted structures were noted.



Figure 5.36 Steps from the Nohoch Mull to an *aguada* at Coba.

Several of these smaller groups were walled and contained small *aguadas* or *aguaditas* as noted above (Figure 5.37). Although the incidence of walled residential spaces has been recorded by several researchers, Acanceh (Quintal Suaste 2000; Quintal Suaste and Ochoa 1996; Quintal Suaste et al. 1999), Becan (Thomas Jr. 1981), Chichén Itzá (Lincoln 1987; Schmidt 1981) Coba (Kintz 1978), Chunchucmil (Vlcek, Garza de Gonzales and Kurjack 1978), Cozumel (Freidel and Sabloff 1984; Peraza Lope 1993), Tulum (Velazquez Valdez 1985), and Xamanhá (Hernandez



Figure 5.37 An *aguadita* adjacent to a domestic group at Coba.

Hernandez 1992), none reported the incidence of water conservation features as elements within walled domestic units. Though the Coba walled groups appear to define discrete household plots, no dating exists to establish their antiquity with any degree of certainty. The groups were labeled "*aguadita* groups" for this study. Archaeological evidence, cut marks around rims, stairs, and stone embankments suggest the

features were culturally enhanced to increase capacity and improve access. In one instance a stone and earthen dam-like construction that potentially increased the depth of the retention pond an additional two meters was located along one edge of an *aguadita*. The *aguadita* group pattern consisting of a platform, unvaulted structures, a wall, and a small *aguada* seems to be unique to Coba. The pattern represents a highly effective conservation strategy. Based upon initial findings during field survey, *aguadita* groups are most likely repeated throughout the entire settlement area on the periphery of Coba.

Three wells were noted at Coba. The wells are similar in form to wells surveyed at Dzibilchaltún in that they are formed as perforations in the exposed caprock above pools of water located in subterranean chambers. They resemble Type 2 *cenotes* (Roys 1939) at Mayapan as well. Surface perforations for each well were culturally modified as evidenced by tool marks. The wells of Coba differ from wells documented at Acanceh, Aké, and Noh Ichmul where the builders found it necessary to excavate deep circular shafts through thick layers of caprock. Some Coba residents refer to solution-shafts as *aktuns*; a term of reference for caves in other parts of the peninsula. These features were deep vertical-walled shafts that perforated exposed caprock. After sufficient field investigation, several



Figure 5.38 Sacred space inside a *cenote*.

instances where shafts were deep enough to penetrate subterranean reservoirs were noted. Coba has one Type 3 *cenote* (Roys 1939).

Discarded plastic water jars, ceramic sherds collected from the lower surface of the depression, and ritual paraphernalia including candles and votive images (Figure 5.38) placed in niches along the rim similar to sacred objects found in the entrance to a *cenote* at Aké suggest the feature has been

continuously used from ancient times to the present as a source of water for consumption and *zuhuy ha'* for ceremony. The remains of a small platform, several unvaulted structures and two cists (burial chambers) were found on the floor of the depression that contained the *cenote*.

The ceramic collection from water contexts at Coba is dominated by Palmas and Oro Complex ceramics representing a period from A.D. 550 / 600 to 1100 / 1200 (Robles Castellanos 1990). The earliest period Anejo Complex dating from 100 B.C. / A.D. 100 to A.D. 300 / 350 (Robles Castellanos 1990) were discovered in a group with no vaulted structures on the southern shore of Lake Coba. The locational evidence supports the notion that the earliest inhabitants on the peninsula located their settlements near natural water sources.

One of the two caves surveyed in the Coba area undercuts a vaulted structure on the southwestern edge of the Coba Group. This area forms a narrow strip of land separating Lake Coba from Lake Macanxoc. The cave, like many caves throughout the peninsula, is considered to be a sacred place and source of *zuhuy ha'* for ritual. A crudely constructed altar-like feature of unknown age containing a few pottery sherds and skeletal remains was found in the cave. A second cave having a cut stairway leading to a pool of water 15 meters beneath the

ground surface is located in the center of an architectural group 16 kilometers southeast of Coba's central precinct. The corridor and stairway contained fragments of ceramic jars and vessels. The residents of Coba collected small amounts of water from the few caves in the area, but most likely relied more heavily upon the lakes and *aguadas*.

Two *chultunes* were found at Coba. One is located on a terrace with vaulted structures less than 100 meters north of Lake Macanxoc and the other on a platform supporting vaulted structures 500 meters north of Lake Coba. Both *chultunes* had cut-stone necks and funnel-shaped catchment areas. The on-terrace or platform context, proximity to vaulted architecture, nearby lake and low *chultun* density, 0.067 per square kilometer, suggest these features most likely were not essential for human survival at the settlement. Instead, *chultunes* at Coba might have existed for the convenience of a privileged or functioned for purposes other than water storage.

As evidenced by the findings at Coba, lakes, depressions or *aguadas*, *sartenejas*, *haltunes*, caves, and solution shafts provided water for the ancient inhabitants of Coba. In most instances, these features required minimal investments of technology, labor and maintenance to meet those needs. No evidence remains in the archaeological record to suggest that

the elites of Coba controlled access to water resources or used the preferential access to water sources as a basis or source of power that was limited to a select segment of society.

Merida District

Acanceh

The site of Acanceh is located approximately 25 kilometers south-southeast of Merida, Yucatan, Mexico. Acanceh is a third ranked site (Garza and Kurjack 1980) situated in the modern town of Acanceh, Yucatán, Mexico. The mapped area of the site covers 4.428 square kilometers, all within the boundaries of the modern town (Quintal Suaste 2000; Quintal Suaste and Pantoja Diaz 2001). The site is located at 16Q 244800mE, 2303500mN UTM, 20° 48' 50.273" North, 89° 27' 06.975" West in District Number 3, the Merida District (Figure 5.39) of Wilson's physiographic classification (Wilson 1980). Wilson described the district as karst plain having low relief, small hills, mostly small depressions, and some larger circular depressions in southern and western portions of the area. Static phreatic depth from the surface in wells averaged 8.22 meters. Average depths recorded for Acanceh were surprising considering the site is situated squarely in the 10 to 15 meter static water level zone of the National Water Commission's

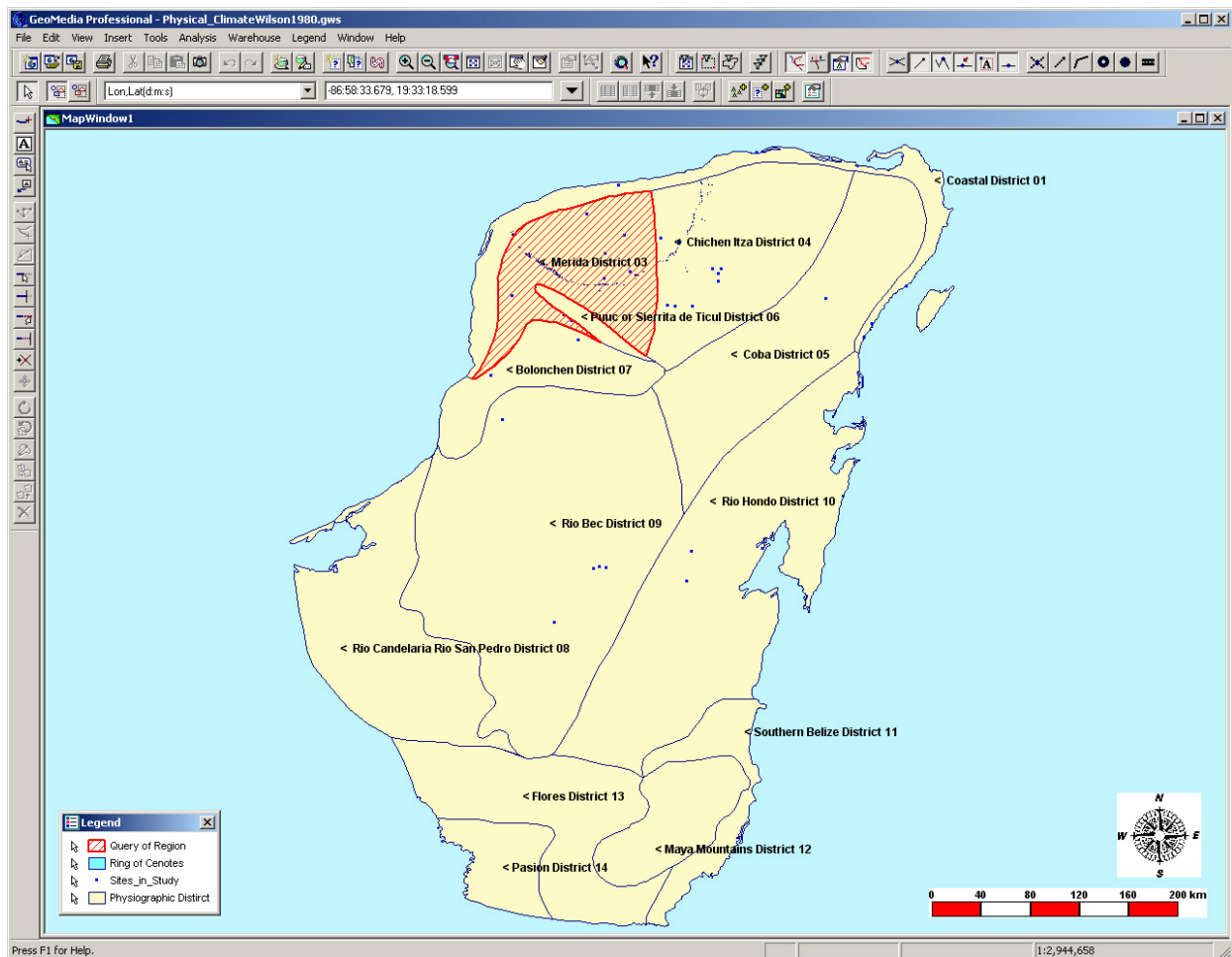


Figure 5.39 Wilson's Merida District in the project GIS.

subsurface hydrological map of Yucatán (Dirección General de Administración y Control de Sistemas Hidrológicos Dirección de Aguas Subterráneas 1988). Average depths to phreatic in the Merida District vary from one meter in extreme northwestern sections to over 30 meters south of the Puuc or Santa Elena District. Measurements taken in this study and the commission's

published data argue for a predominance of wells rather than adaptive strategies to store water.

Analysis of ceramics recovered from excavations in Structure 1, the pyramid, and the Stucco Palace, date the pre-Hispanic occupation from the Late Preclassic Period (300 B.C. to A.D. 300) to the Late Post Classic Period (A.D. 1300 - 1450) (Quintal Suaste and Ochoa 1996). Ceramics collected from a *cenote*, cave, and well suggest use during the same periods.

Desire Charnay provided a description of the pyramids of Acanceh after his visit in 1881. Andrews IV and Brainerd (1958) completed survey of the site in 1958. From 1989 to 2000, Quintal directed the Acanceh Archaeological Project. Quintal Suaste provided a copy of the 1999 project map of Acanceh for this study Quintal Suaste and Pantoja Diaz (2001), Quintal and Ochoa (1996), Quintal et al. (1999). The map (Figure 5.40) was used to plot the location of architectural and settlement units in the GIS with water features surveyed in the field.

The archaeological site is interspersed among house lots in the modern town. I negotiated with property owners to acquire permission to investigate the residential clusters. The pre-Hispanic settlement contains a central precinct having several Classic Period monumental or public structures and a periphery of, at minimum, five distinct settlement clusters

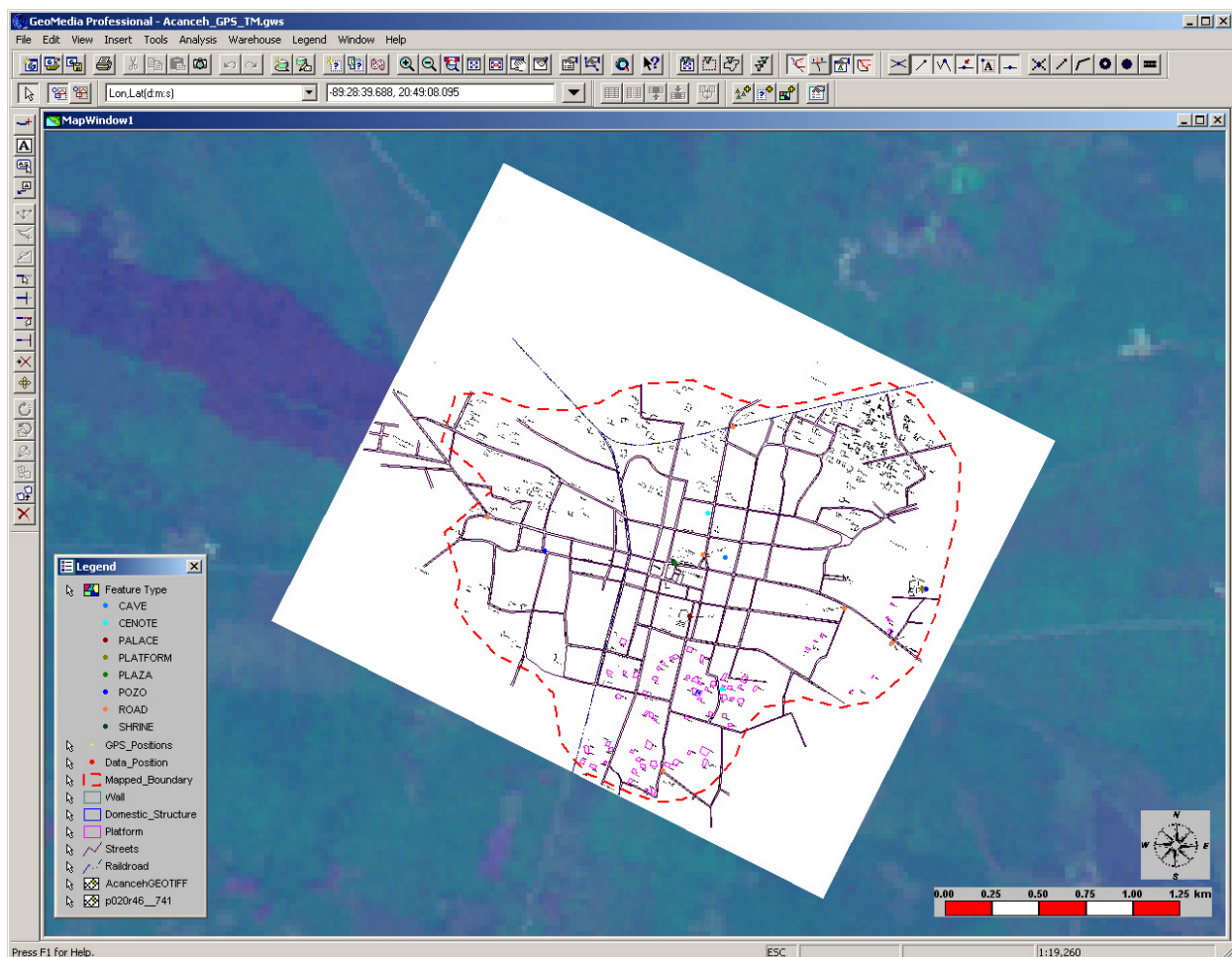


Figure 5.40 Map of Acanceh in the project GIS, adapted from Quintal Suaste and Pantoja Diaz (2001). Landsat TM courtesy of NASA.

containing nonpublic architecture including domestic platforms and house mounds. As is the case throughout this paper, no attempt was made go beyond a general distinction of nonpublic structures to particular subcategories such as Ringle and Andrews V's (1990) Type 1 and Type 2 for Komchen. In every instance where structures associated with water features are cited, the amount of mounded remains or rubble including

identifiable wall sections was sufficient to consider the area domestic space.

Examples of two principal structures, the Stucco Palace with a stucco façade, and Structure One a four-sided stepped pyramid having two large stucco masks bordering the top of each stairway made famous and photographed by Teobert Maler are best illustrated in Marquina (1951). Water features were found in association with three of five settlement clusters. No water features remain in the area of the central precinct.

Two *cenotes*, one *aktun*, and two wells were surveyed at Acanceh. One well east of the central plaza appeared to be pre-Hispanic; the other most likely dates to the Colonial Period. There are no known *chultunes* in the archaeological site. The marked absence of *chultunes* supports the notion that the ancient Maya preferred to excavate wells in areas where they were able to reach the phreatic. One *cenote*, Olin Chen, is situated in the center of a group of low platforms. No traces of vaulted structures were found nearby. A stone alignment on top of a platform to the south of Olin Chen, could possibly be the remains of a vaulted structure. Olin Chen had a carved stairway leading to a small pool of water approximately 7.5 meters below the ground surface.

An ancient well is situated less than 20 meters east of a stairway leading to a vaulted structure on top of a four-meter high platform 1.25 kilometers east-northeast of the central precinct. The well contains the remains of a crudely constructed 50-centimeter high brocal on the northwestern side of its mouth. A series of notches, presumably footholds, were carved into the vertical limestone wall. These five-centimeter deep notches are spaced approximately seventy-five centimeters apart from the mouth to the debris filled base. The associated mound is not a part of a larger settlement unit. Instead, the structure appears to be the focal point of a cluster of small platforms that supported perishable structures. The well is directly associated with the vaulted structure to its west and there are no other water features in the area to suggest the common households in the nearby cluster relied on other sources of water or water storage capabilities beyond water jars. The absence of evidence of bounding features such as walls or enclosures or placement in private or semi-private space such as platforms suggests the inhabitants from nearby domestic areas were permitted to draw water from the well. The occupants of vaulted structures might have excavated the well or simply claimed property near the well.

Aké

Aké, a second order site (Garza and Kurjack 1980), is located approximately 35 kilometers east of Merida, Yucatan, Mexico. The archaeological zone is situated in and around the modern town of Hacienda Aké, Yucatán. The site center is located at 16Q 260834mE, 2317863mN UTM, 20° 56' 44.802" North, 89° 17' 59.848" West in the eastern portion of the Merida District (Wilson 1980). The mapped portion of Aké covers an area of 1.266 square kilometers (Figure 5.41). Roughly 2.4 kilometers of wall course through a portion of the site. Architectural remains exist to the north, east, and south of the mapped portion of the site.

A platform near Cenote Xkojil two kilometers north northwest of the central precinct represents the greatest distance from the site core to an architectural group surveyed at Aké. Time and funds did not permit survey of a continuous transect between Aké and the Cenote Xkojil area. Reconnaissance of several 250-meter sections between the central precinct of Aké and the Cenote Xkojil group were accomplished to determine whether or not the area was continuously settled. The procedure was modified and adapted from (Dunning 1992). No structures or

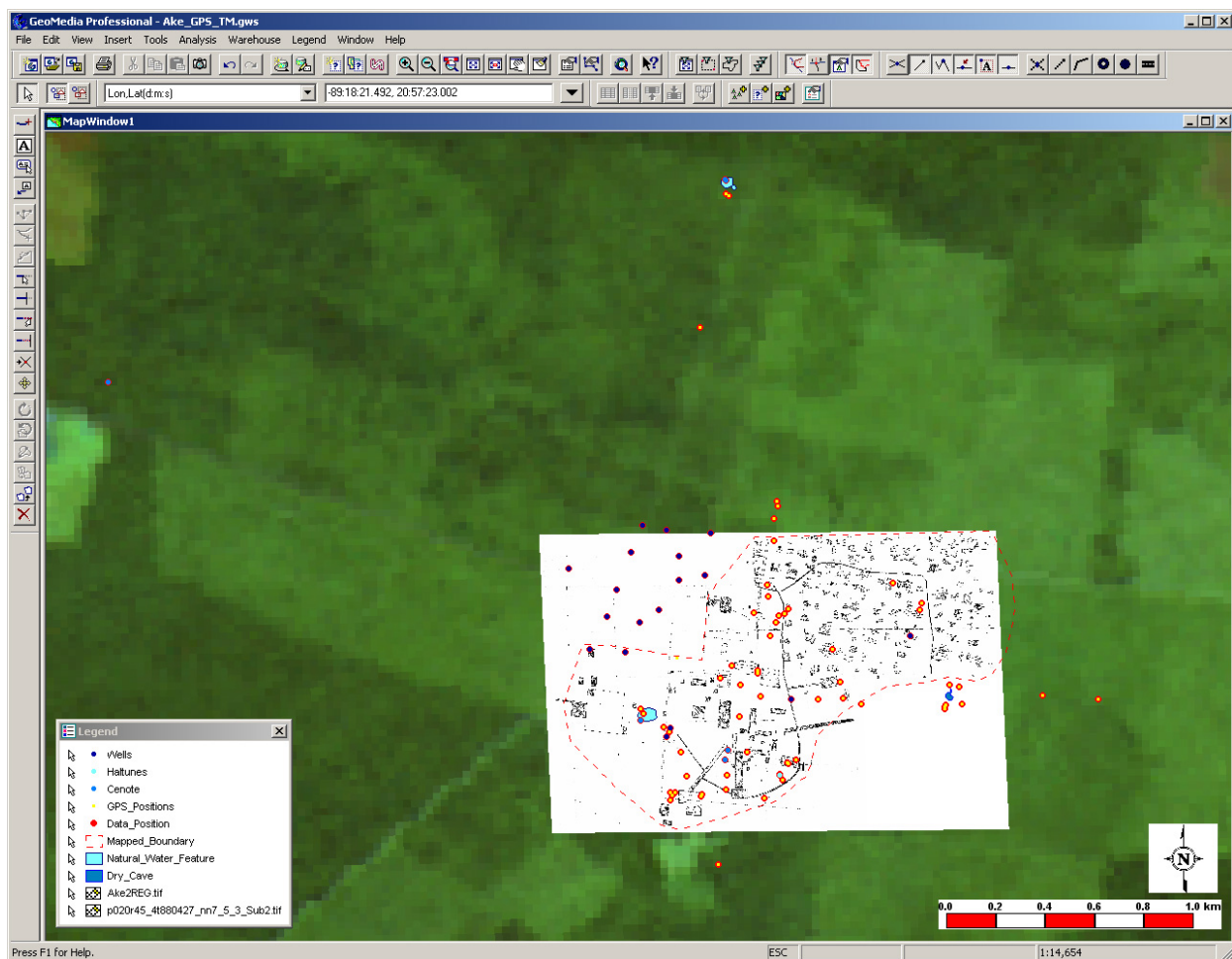


Figure 5.41 Map of Aké in the project GIS, adapted from Maldonado Cardenas (1985). Landsat TM courtesy of NASA.

mounded remains exist between the two areas. Therefore the argument might be made to consider the group located at *Cenote Xkojil*, a new site. Ceramics collected in the waters of *Cenote Xkojil* are from the Cehpech Ceramic Complex and date its use to the Terminal Classic Period. Much of the pitted landscape surrounding Aké is covered with thick scrub and henequen fields. The modern-day town of Hacienda Aké is one of the few

locations in Yucatán with an operational henequen factory. Roys and Shook (1966) mapped the central precinct of Aké in 1966. Over several field seasons, Quintal Suaste, Sierra S., and Vargas de la P. surveyed and mapped structures outside the site core and modified the original Roys Shook 1966 map (Maldonado Cardenas 1982, 1985).

A 32-kilometer long *sacbe* links Aké to the archaeological site of Izamal to the east. The walled central precinct houses several monumental buildings. Four *cenotes* exist at Aké. Two of these are Type 2 (Roys 1939) and two are Type 3. One of the Type 3 *cenotes* has no access to water due to a blocked. Two dry caves were explored as well. One *cenote*, named *Cenote Kanchul* is located 350 meters west of the main plaza. Another dry *cenote* was located approximately 150 meters south of the central plaza. No *chultunes* were found during survey. A "bee-hive vault" (Roys 1966) or chamber is excavated into the upper floor of Structure Number 2, an 8.5-meter tall four-sided Puuc style pyramid located on the western side of the central plaza (Figure 5.42). Evidence of multiple layers of fine plaster caused Roys and Shook (1966) to speculate that the feature might have been a *chultun*. The chamber has since collapsed

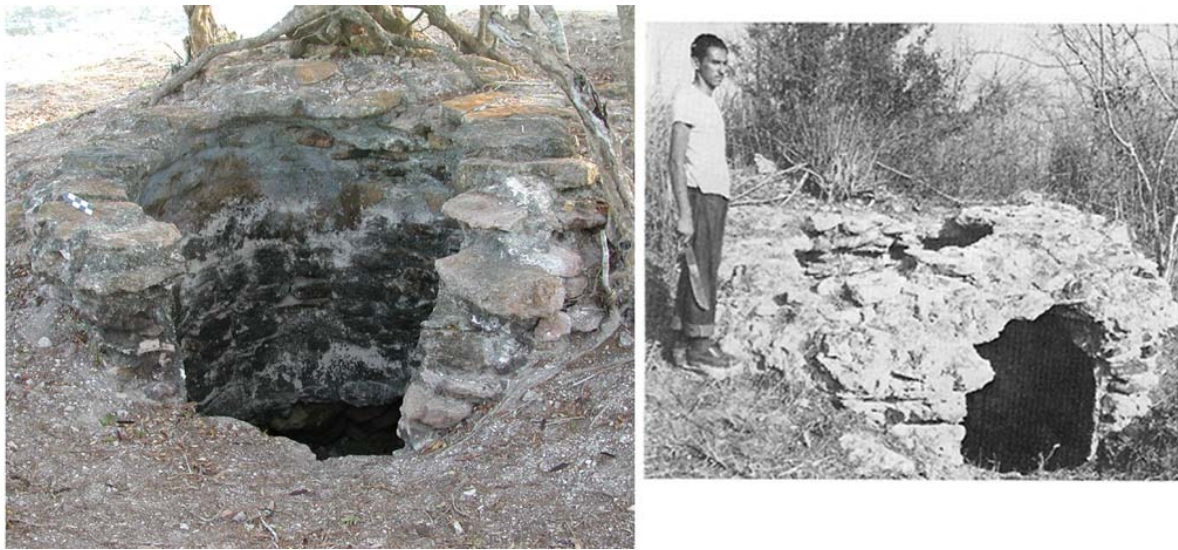


Figure 5.42 Left, feature at top of Structure 2 Aké, right, Roys and Shook (1966).

destroying any evidence that might help establish whether or not the feature was a *chultun*. Maldonado Cardenas (2001 personal communication) believes the feature was a colonial period kiln. At Izamal, I photographed and recorded the dimensions of a limekiln that appeared to be similar in form to the feature on Structure 2 favoring Maldonado Cardenas' interpretation of the structure as a kiln.

Seventeen wells were investigated at Aké. Based on initial examinations, three of the 17 wells appear to be pre-Hispanic. The remaining wells follow the rectangular grid street pattern in the municipality of Hacienda Aké established in modern times. Depth to static levels for wells measured averaged around ten meters. This figure is consistent with 1986 data for

the area provided by the National Water Commission in Merida, Mexico (Direccion General de Administracion y Control de Sistemas Hidrologicos Direccion de Aguas Subterraneas 1988). These data position Aké on the northern edge of the 10 to 15 meter zone, well below the maximum for ancient Maya technology. For that reason the expected routine includes wells as part of the adaptive strategy at Aké.

During the survey, several *sartenejas* and one *haltun* were discovered. The *sartenejas* were near low platforms. *Sartenejas* are shallow depressions in the ubiquitous caprock covering much of the peninsula. They rarely measure more than a few centimeters deep but frequently measure in excess of one meter in diameter. During the rainy season, *sartenejas* capture and hold water. Diego de Landa (1978) mentioned the collection and use of rainwater for consumption by the indigenous inhabitants. The *haltun* located 400 meters south southeast of the central plaza, is one meter east of a circular depression cut into the caprock (Figure 5.43). Both features are three to four meters southeast of the remains of several oval-shaped domestic structures. The remains of several vaulted structures are located within 50 to 100 meters of the *haltun*. According to local workers, the *haltun* contains water in all seasons. The



Figure 5.43 *Haltun* left, associated circular feature right.

shallow 20-centimeter deep pool of water is 80 centimeters below ground level. The slightly ovoid-shaped pit is unlike any perforation or depression documented during survey or noted in the literature.

Prior to excavation, the pit was filled with soil, leaf litter, various stones and pebbles, and several bushes. The depression measures 1.53 meters at its greatest width and 1.40 meters at the narrowest. Considering the pit was cut into hardened caprock and its diameter is larger than wells noted elsewhere, the notion that the pit is the remains of an unfinished well was ruled out. The depression might have been a Colonial Period reservoir for watering livestock. However, the nearby *haltun* argues against this notion. The pit might have

functioned for purposes other than water storage, but related to the *haltun* in some way.

Considering the central location of the pit among several architectural groups containing vaulted and non-vaulted domestic structures, the immediate water source, and the high temperatures that develop in caprock exposed to the midday sun, it is possible that the feature was used to soften maize kernels in limewater prior to grinding. There are no precedents to cite in support of this notion, nonetheless Vogt (1970) noted a similar but slightly different process among the Maya of Zinacantan, a *municipio* in the Highlands of the Modern-day state of Chiapas, Mexico. The key difference being the Zinacanteco women speed up the softening process by boiling the maize kernels in ceramic jars rather than soaking them over a longer period in stone. Diego de Landa (1978) mentioned Maya women soaking the entire maize fruit including husk and silk over night in lime and water. The feature might relate in some way to the production of henequen as well. The industry thrived in the Yucatán Peninsula until the later 20th century and is still active at Aké but on a appreciably smaller scale.

The depression has vertical-cut walls similar to ancient wells. Curiously, the depression is only 40 centimeters deep and completely within the hard caprock. This feature was

capable of holding water. During excavation, three pieces of ceramics were recovered from the lowest level, 19 to 37 centimeters, of the pit. All of the ceramics belong to the Cehpech Ceramic Complex. Two sherds were from jars and one from a flat-base bowl. At present, the exact function of this feature remains a mystery.

Survey of the site of Aké produced one *aguada*. A local henequen factory disposed byproducts produced during extraction of henequen fibers from plant leaves in the *aguada*. The *aguada* formed by a natural depression measures 24.95 meters wide by 32.7 meters long. An artificial canal leads from the northeastern rim of the depression to an abandoned Colonial Period henequen-processing building, located 250 meters to the north. There is no evidence to suggest that the *aguada* itself was excavated using modern machinery, so it might have provided water to the ancient inhabitants of the area. No evidence of a stone rim or attempts to line the *aguada* is visible. There are two wells inside the *aguada*. Similarities with other ancient wells suggest the one near the southern rim is Prehispanic. The other well located inside the northwestern edge appears to be colonial. Placement of these wells inside the *aguada* is similar to the practice of excavating *buktes* or well shafts in *aguadas*

at Uxmal (Huchim Herrera 1991) and Rancho Jalal Stephens (1988).

Dzibilchaltún

Dzibilchaltún is a second-ranked settlement (Garza and Kurjack 1980) 14.2 kilometers north northeast of Merida, Yucatán. A large *cenote*, *Cenote Xlakah*, is located in the central precinct of the site at 16Q 230066mE, 2334425mN UTM, 21° 05' 27.672" North, 89° 35' 53.572" West. Unlike the Type 1 *cenotes* (Roys 1939) located farther inland such as *Cenote Sagrado* at Chichén Itzá, those found near the coast are typically smaller in diameter and the water surfaces are understandably nearer the ground surface, making access less difficult. Dzibilchaltún is the northernmost site surveyed in the Merida District (Wilson 1980). Phreatic depths in the area measure five meters or less (Direccion General de Administracion y Control de Sistemas Hidrologicos Direccion de Aguas Subterraneas 1988). Considering the adaptive options afforded the ancient inhabitants of Dzibilchaltún, the predicted strategy is excavation of wells to extract water rather than construction of *chultunes* to store water. The water surface in all measurable wells was between 4.1 and 3.2 meters beneath the surface.

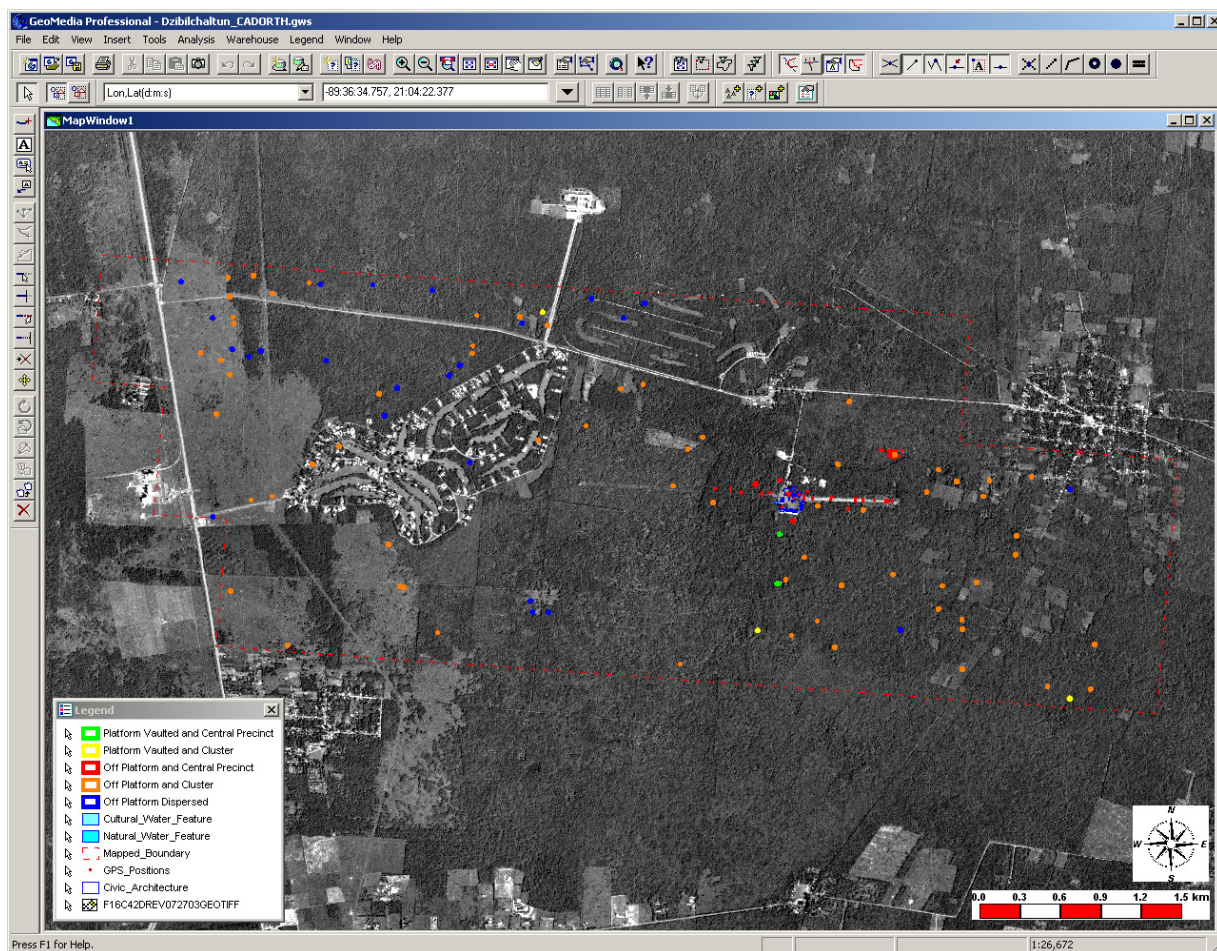


Figure 5.44 Dzibilchaltún in the project GIS.

The mapped site of Dzibilchaltún covers an area measuring 19.794 square kilometers (Figure 5.44). During its florescence, Dzibilchaltún's sustainability area must have included a significantly large portion of the littoral. Several researchers have proposed that salt from the Cienaga and other marine resources were trade resources exploited by the ancient inhabitants of Dzibilchaltún and other coastal sites (Andrews 1980; Andrews IV 1969). Brainerd (1942) and Andrews IV (1942)

completed the earliest archaeological investigations to take place at Dzibilchaltún. In 1954 and 1955, Shook (1955) investigated modern stone quarrying taking place in the Komchen Group. Later, Andrews IV and Rover (1973) published a report on stone tools discovered at the site. Between 1956 and 1966, Andrews IV of the Middle American Research Institute, MARI. George Stuart worked in Dzibilchaltún from 1958 until 1960 exploring the causeways and mapping central portions of the site. Kurjack (1974, 1978) studied changes from dispersed clusters to a concentration of vaulted elite and civic or religious structures in central areas of the site and the subsequent changes in social complexity these changes in settlement patterns indicate for Dzibilchaltún.

Stuart, Scheffler, Kurjack and Cottier (1979) published the map of Dzibilchaltún. Andrews IV and Andrews V (1980) described restoration and excavation of principal structures and registered more than 25 stelae. Cottier (1982) analyzed ceramics as well as other artifacts and features recovered from test pits and surface collections completed at 710 locations throughout the settlement. Repetto Tio and Maldonado Cardenas (1986) excavated portions of the system of causeways and restored the southern edge of Causeway Number 1 at the site.

Since 1992, Maldonado Cardenas has directed the Dzibilchaltún Archaeological Project for INAH.

I was able to locate 97 out of the 112 wells and caves Cottier (1982) reported for Dzibilchaltún. Most of the wells observed had small openings measuring between 50 and 75 meters in diameter. Many of these features are natural openings above subterranean chambers and are labeled *cenotes* by some researchers. Several had rectangular brocals constructed on top of culturally modified natural perforations in the caprock. The perforations lead to subterranean chambers and passageways that in all likelihood course through the entire site. Other wells had round brocals or circular openings cut into the caprock. The rectangular cut-stone brocals resemble similar curbs and modifications found at other sites in this sample.

Dzibilchaltún has the highest density of wells per square kilometer of any settlement area in this study. Density of wells per square kilometer was calculated for concentric zones radiating outward from the center of architectural mass near *Cenote Xlacah*. The density of known wells distributed over the entire mapped area of Dzibilchaltún (Stuart et al. 1979) totals 4.9 per square kilometer of mapped area. Additional calculations were made for areas within a 500, 750, and a 1000-meter radius of *Cenote Xlacah*. Within the 500-meter zone, there

are seven wells, and a calculated density of 7.9 per kilometer. When the zone is expanded to 750-meters, 15 wells occur within the boundary, and a calculated density of 7.7 per kilometer. A total of 21 wells were found within a radius of one kilometer of the central precinct. The density of wells in this area is 6.1 per square kilometer. Well frequencies decline as distance increases from the core. Interestingly, this pattern is opposite to *chultun* frequencies at Becan, Chichén Itzá, and Calakmul. At these sites, frequency of constructed water management features increases as distance increases from existing natural water resources, then declines in the periphery as architecture becomes dispersed. The fall off in densities is typical of observations for other features such as *chultunes* at other sites in the region.

I excavated a well located at the base of a stairway leading to a low platform supporting the remains of four structures or rooms and one small mound (Figure 5.45). The platform is 320 meters north of the Seven Dolls structure. At first glance, the feature appeared to be a *chultun*. If excavation revealed that the feature was a *chultun*, it would be the only documented *chultun* at Dzibilchaltún. Excavation proceeded through various sized stones and boulders, soil, and



Figure 5.45 Well at Dzibilchaltún after excavation.

organic material to a depth of 3.8 meters where solid bedrock was encountered.

Before excavating, I thought the feature would be sufficiently deep to encounter water, a depth of 4.6 meters for the nearest well located approximately 362 meters to the southeast, but solid bedrock at 3.8 meters and no water suggest this feature and perhaps others like it at Dzibilchaltún did not penetrate the saturated zone. They might have functioned

for water storage like *chultunes* instead of extraction like conventional wells. No fractures, clay pans, lenses, or hardened subsurface impervious calcite pans were noted that could have produced a perched reservoir of fresh water or permitted recharge of the feature from the phreatic located several meters below.

Sea level today is between one to two meters above Late to Terminal Classic Period (A.D. 850 - 900) levels (Dahlin et al. 1998; Dunn 1990; Dunn and Mazzullo 1993; Freidel and Scarborough 1982; Graham 1989; McKillop 1989, 1995, 1996, 2002). Paleo-climatic data suggest the climate of Yucatán was similar or slightly drier than today (Dahlin 1983; Deevey, Brenner and Binford 1983; Hodell, Curtis and Brenner 1995; Leyden 1987). Hence the dry well suggests this feature and others at Dzibilchaltún might have not have functioned like traditional wells. Other than a few pieces of Colonial material, a small quantity of Copo 2, Terminal Classic Period ceramics were recovered from the well. Additional investigation and excavation of similar features is needed to come to determine whether or not this feature and others like it at the site were wells or an localized type of subterranean water storage reservoir.

Earlier I mentioned that some of the Dzibilchaltún wells were culturally enhanced natural features. A total of three of the 97 wells located are found off in platform contexts in the Central Precinct area and two are on platforms having the remains of vaulted architecture within the Central Precinct as well. Beyond the Central Precinct, 65 wells are off platform in areas of clustered architecture, 24 are off platform dispersed in areas having sparsely distributed architecture and two are on platforms having evidence of vaulted architecture. As expected, the distribution of wells at Dzibilchaltún plotted in the project GIS follows the distribution of settlement units across the landscape (Figure 5.46). If a significant amount of the wells are natural features, then the observed relationship suggests that probably settlement followed the distribution of natural water resources.

Dzibilchaltún's Prehispanic chronology extends from the Middle Preclassic Period or Middle Formative (800 B.C.) through the Decadent or Late Postclassic Period (A.D. 1546). In general, the pottery collected from water feature contexts are Copo 2 and Zipche Complex ceramics dating to the Terminal Classic Period and Early Postclassic Periods (A.D. 830/950 to 1000/1200) respectively. There were two exceptions, both in the central precinct. One well just to the east of a platform

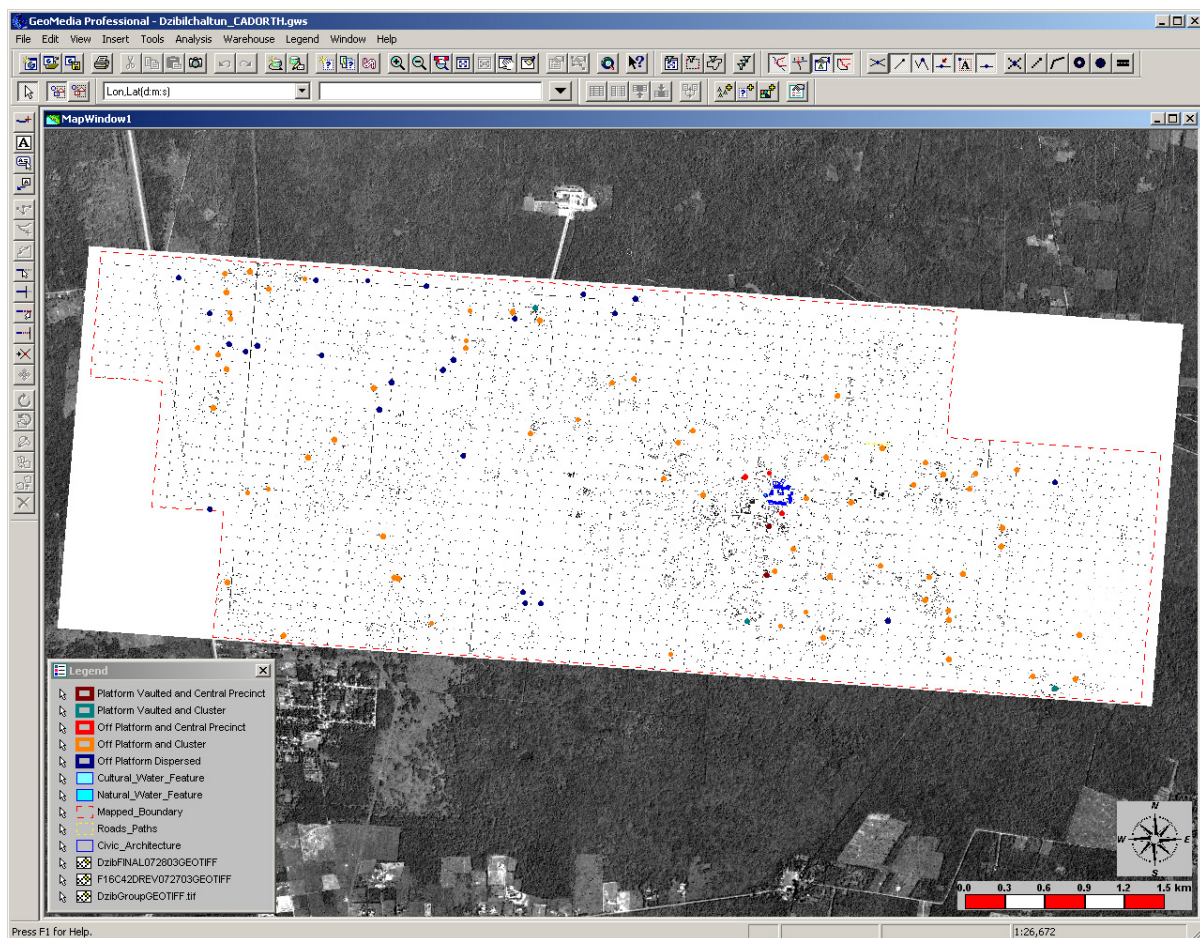


Figure 5.46 Wells at Dzibilchaltún plotted by context in the project GIS. Map adapted from Stuart et al. (1979).

on the south edge of Causeway Number 1, contained Piim Complex, Saban Unslipped: Saban jars that date to the Early Classic Period (A.D. 200 to 600). Another well adjacent to vaulted structures, 60 meters south of Structure 44 yielded Classic Period Piim Complex, Batres Red Group jars.

Cottier (1982) reported that the most abundant frequencies of Formative Period ceramics were found in western portions of the site and at the site of Komchen. The absence of early

ceramics around *Cenote Xlacah* does not fit the model for early occupations near available water resources. Brainerd (1958) recorded Late Formative sherds in the central zone near the *cenote*. As is the case in many contexts throughout the Yucatán Peninsula, recent occupations destroyed evidence of early settlements. Cattle ranching during the colonial and modern periods at Dzibilchaltún destroyed ceramic remains as well. If a substantial number of the wells at Dzibilchaltún are natural, establishing residences in close proximity to *Cenote Xlacah* might not have been essential for the earliest inhabitants of Dzibilchaltún.

Mayapan

The site of Mayapan is located approximately 43 kilometers south southeast of Merida, Yucatan, Mexico. Mayapan, (Figure 5.47) a second ranked site (Garza and Kurjack 1980) is two kilometers south of the modern day town of Telchaquillo, the site of a fourth-ranked ancient Maya settlement. Mayapan was first mentioned by Friar Diego de Landa in 1566 (Tozzer 1941). Stephens (1988) described village women descending an irregular stone stairway cut into the rim of a large *cenote* on the plaza in Telchaquillo to collect water with ceramic vessels and noted

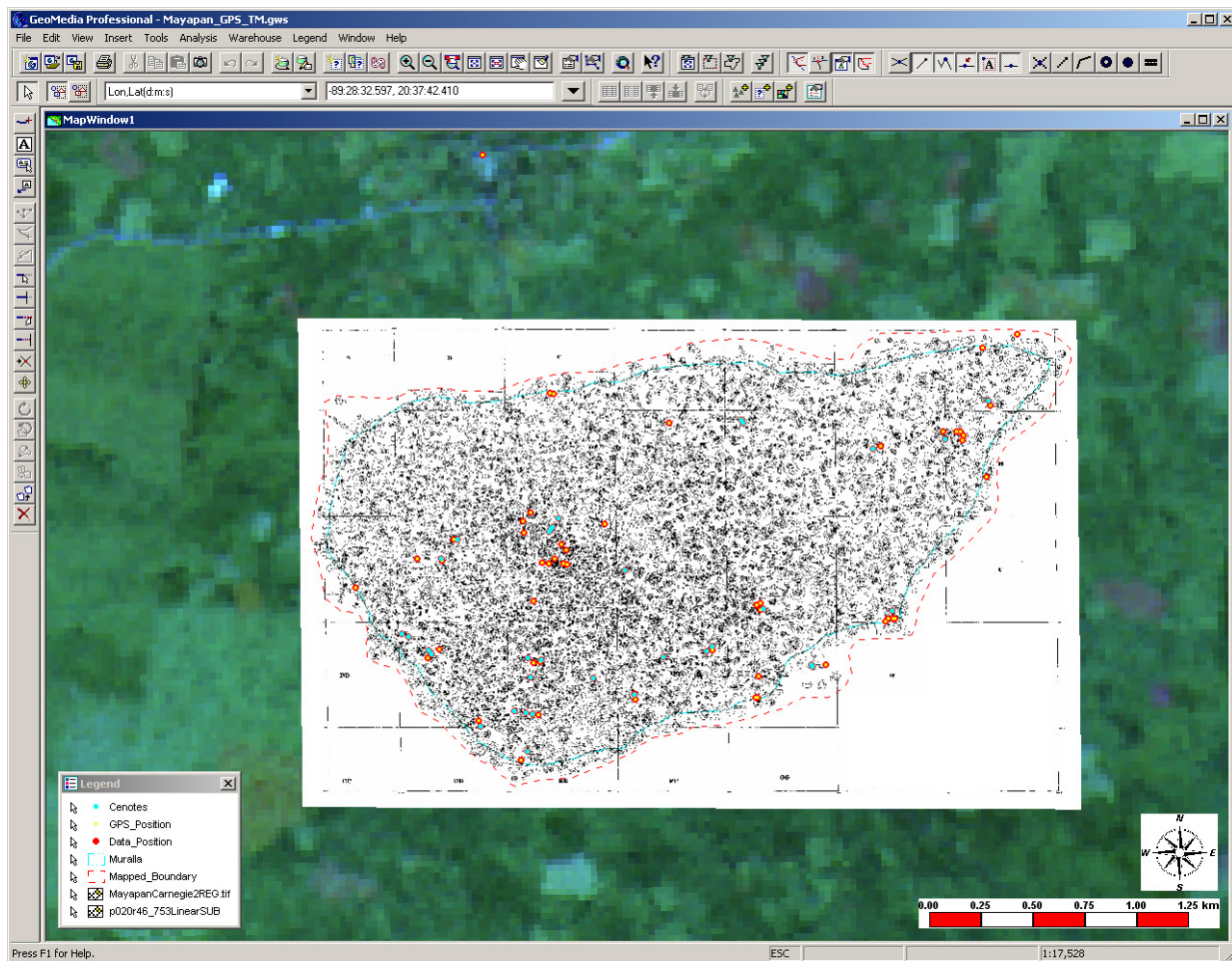


Figure 5.47 Map of Mayapan in the project GIS, adapted from the Carnegie Institution of Washington (1962). Landsat TM courtesy of NASA.

several structures situated in the central precinct at Mayapan located a few kilometers away.

Although Carnegie Institution archaeologists under the direction of Morley (1938) visited and surveyed the wall around Mayapan in 1938, excavations were not started until 1942 when Brainerd (1942) dug stratigraphic trenches to recover pottery. In the late 1940s and throughout the 1950s extensive survey and

excavations were completed by the Carnegie Institute (Pollock et al. 1962). Since 1996, an ongoing consolidation and restoration project under the direction of INAH archaeologists is underway at the site.

El Castillo, a small-scale replica of the four-sided stepped pyramid having the same name at Chichén Itzá, is located at 16Q 243561mE, 2283086mN UTM, 20° 37' 46.208" North, 89° 27' 39.071" West. The site is situated in the south central portion of Wilson's Merida District (Wilson 1980). In general the district is a karstic plain with low relief and some small depressions and some larger circular depressions and cenotes in southern portions. The site was surveyed by Morris R. Jones of the Carnegie Institution of Washington from 1949 through 1951. The Jones map was revised in 1957 to include detail of structures located in the central precinct by Proskouriakoff (1957), and was subsequently published by the Carnegie Institution in 1962 (Pollock et al. 1962).

The Carnegie map of Mayapan covers an area measuring 5.33 square kilometers. Roughly 4,495 square kilometers of the settlement and approximately 4,000 structures are enclosed within an 8.96-kilometer long great wall constructed of limestone having seven major and five minor gates. Published depth to phreatic levels in the region measure between 12 and

15 meters (Direccion General de Administracion y Control de Sistemas Hidrologicos Direccion de Aguas Subterraneas 1988). Project measurements averaged between 9.7 and 12.45 meters, placing the site well within the area where wells rather than *chultunes* would have been the preferred active adaptive strategy.

The ring of *cenotes* is perhaps the most significant geological factor that impacted the settlement decisions of the ancient inhabitants of Mayapan. As discussed earlier, the distribution of sinkholes known as the ring of *cenotes* appears to be related to the Chicxulub impact event that occurred around 64 million years ago. The landscape around Mayapan is dotted with 19 Type 2 and three Type 3 (Roys 1939) *cenotes* that resulted from weathering associated with an extensive system of caves located beneath the site. Pollock et al. (1962) reported 26 *cenotes* inside the wall at Mayapan. Many *cenotes* have several openings, some referred to by local inhabitants using different place names or toponyms consisting of the specific location name and "well" or well as the generic referent. One *cenote*, *Cenote Sac Uayum*, lies 72 meters beyond the southeastern portion of the great wall. The remaining 21 *cenotes* surveyed were inside the wall.

Pollock et al. (1962) fittingly argued that it is highly unlikely that many comparably-sized sites having such a comparable concentration of *cenotes* exist in the northwestern peninsula. The relief, subsurface geology and hydrology, and the general physical environment immediately outside the wall at Mayapan varies little if any at all from inside space. There is no reason to assume that the density of *cenotes* per square kilometer in the nearby area would vary significantly from the 4.7 average calculated for the walled-site. The possibility does exist that the complex network of subterranean chambers and passages at Mayapan is unique to the area and a fall off occurs beyond the walled area. I was unable to allocate the additional time to survey beyond the great wall, so was unable to confirm the assumption. Clearly, the number and relative ease of access as well as year-round reliability of *cenotes* as sources of water made active adaptive strategies such as excavation of wells or construction of *chultunes* unnecessary at Mayapan.

At Polbox, a crude stairway worn from use and littered with broken water jars (Figure 5.48) leads to a pool of water 15 meters beneath the surface. The Hocaba - Tases Complex pottery found in *Cenote Polbox* date its use to the Postclassic Period (A.D. 1200/1300 to 1450).



Figure 5.48 Stair at Cenote Pol-box with broken ceramic jars.

Cenotes occur randomly throughout the site. Other than the architecture within the walled central precinct, the distribution of structures within the great wall is uniform and does not suggest preferential access to water sources at the site existed. Additionally, there is no evidence of preferential location of certain classes of architecture or features near water to suggest that hydrological management contributed to centralization of power at the site. If the

density of *cenotes* inside the walled area was substantially higher than outside the wall, there might be an argument for the wall excluding certain people from water sources. However evidence to confirm higher densities is not available.

With the exception of one piece of Cochuah Complex ceramics (A.D. 300 - 600) collected from *Cenote* X-Coton and one piece of Motul Complex (A.D. 600 - 800) found in *Cenote* Nac-che Burro, the pottery collected at Mayapan was representative of collections by others suggesting the principal occupation of the site and use of water resources occurred between A.D. 800 and 1450.

Exploration of portions of the subterranean network at Mayapan and survey data were collected by undergraduate student Eunice Uc Gonzales from the Universidad Autonoma de Yucatán for her thesis on sources of clay. Uc Gonzales published her results in 1997 as part of the Mayapan Archaeological Project. Unfortunately the informe, a public record, was not found in the archaeological section's files at the Regional INAH office in Merida, Yucatán therefore these data were not considered for this research.

Puuc or Serrita de Ticul District

Uxmal

Uxmal is a first-ranked site (Garza and Kurjack 1980) situated at 16Q 210855mE, 2253847mN UTM, 20° 21' 39.061" North, 89° 46' 10.908" West, approximately 70 kilometers south of Merida, the modern capital of the State of Yucatán, Mexico. The site is on the southern border of Eugene Wilson's Puuc or Serrita de Ticul District (Figure 5.49) near the conjunction of three zones including the Bolonchen, Merida and the Puuc (Wilson 1980). The Puuc District is characterized by a 120 kilometer long northwest to southeast trending ridge that follows a fault line. The area has several caves and few natural sources of surface water. The climate in the Puuc District is Köppen type Aw0, (tropical and hot, low relief, sub humid with rainy summers) and experiences mean average rainfall between 900 and 1100 millimeters, real annual evapotranspiration between 1000 and 1100 millimeters, and average temperatures greater than 22 degrees centigrade (INEGI 2001a, b, c).

For the ancient Maya, the valleys in the Puuc with their deep fertile soils were highly desirable areas for cultivation but much less desirable locations for finding reliable sources of water for human consumption. See Dunning (1992) for a

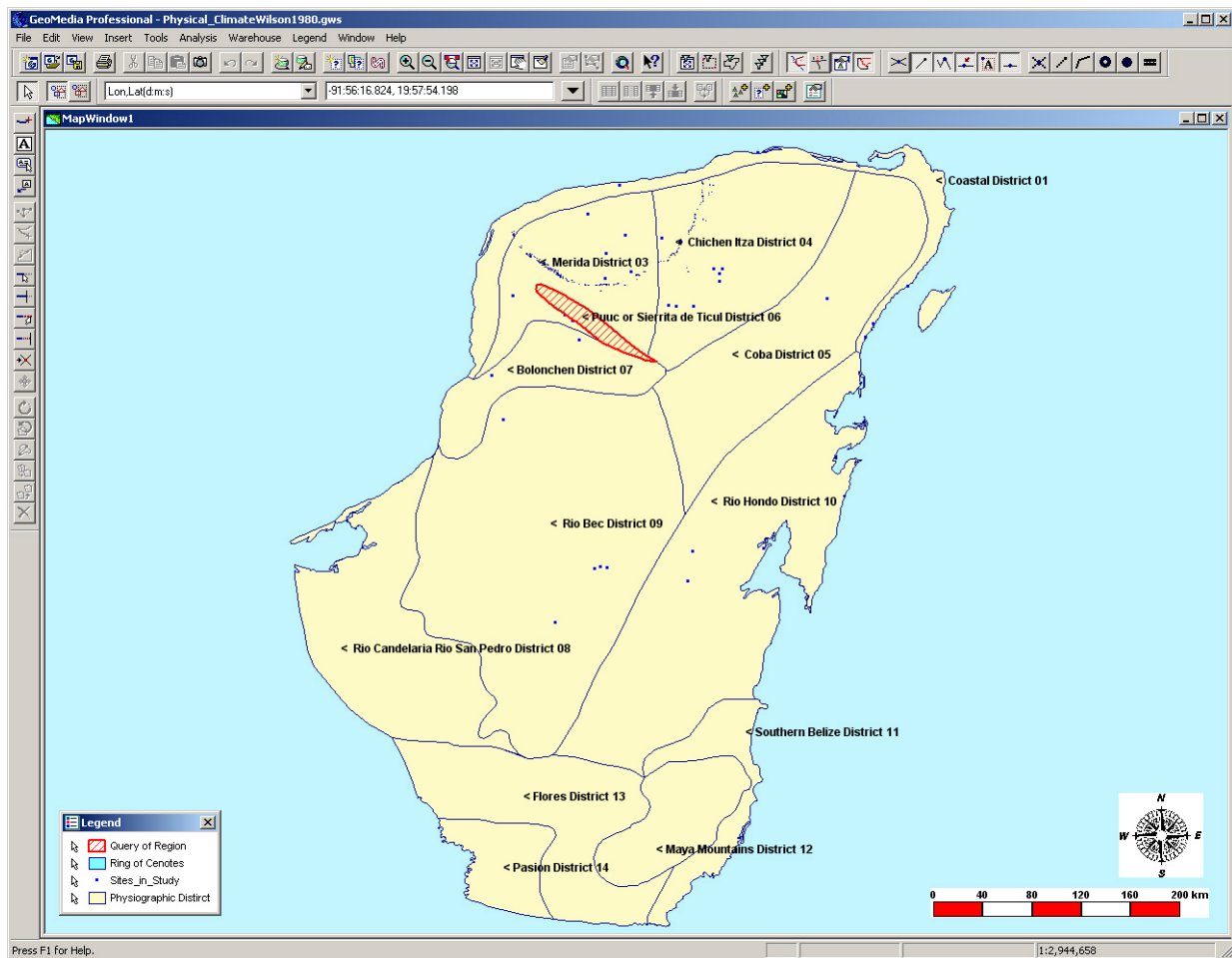


Figure 5.49 Wilson's Puuc District in the project GIS.

detailed description of the physical environment of the Puuc area of Yucatán. Measured depth to aquifer in the area varies from 30 to 50 meters beneath the surface (Dirección General de Administración y Control de Sistemas Hidrológicos Dirección de Aguas Subterráneas 1988). Therefore, I did not expect to find evidence of prehistoric wells at the site. Uxmal lies near the 40-meter cline. The area has a small number of water sources

including naturally occurring *aguadas* found in some depressions, a few *cenotes*, and caves, but on the whole lacked ample water resources for human settlement without active adaptive strategies that required significant investment of energy to construct water storage features or modify the base of natural depressions rendering them impermeable.

Stephens (1988) wrote an early account of the site. Wittfogel (1957) cited Stephen's ideas about the immense reservoir of water provided by the ubiquitous *chultunes* and *aguadas* of Uxmal. Pollock (1980) suggested that Waldeck (1838) published the earliest map of Uxmal. However, Waldeck's map is unavailable. Catherwood surveyed and produced a map of the site between 1841 and 1842 (Stephens 1988). Pollock considered Holmes' maps (1895:plates viii & ix) the best examples of early maps of Uxmal. The Holmes plan map appears to be based on Catherwood's sketch. Between 1886 and 1894 Maler explored the Yucatán Peninsula (Maler 1997). During a visit to Uxmal, Maler (1977: 233 Fig 4.7) described and sketched several structures and architectural details and documented a *chultun* situated on the platform supporting the Governor's Palace and House of the Turtles. Pollock (1980) included the previously unpublished Tulane map of Uxmal dated 1930 and rightly considered it to be the most extensive map of the site. The Tulane map, although

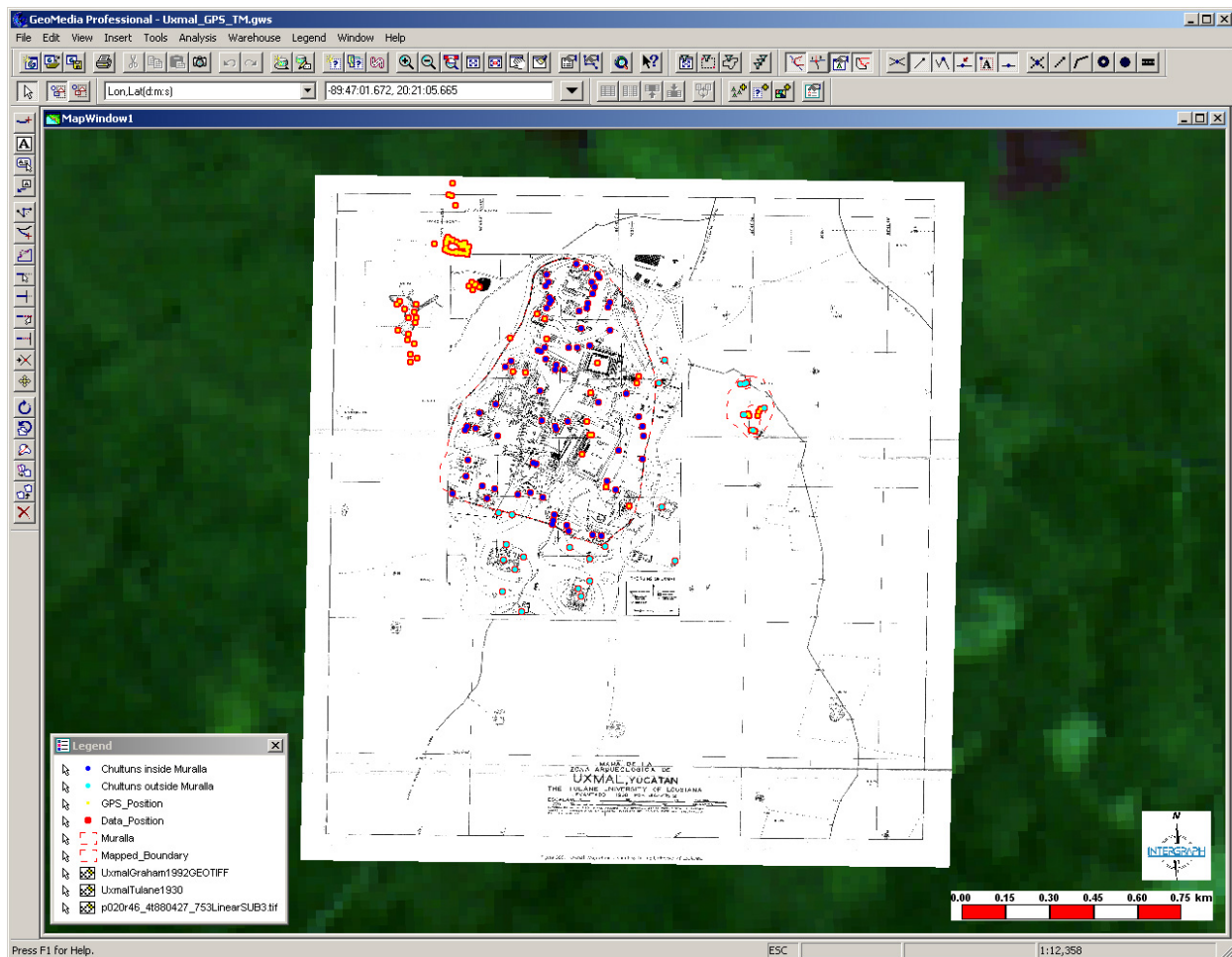


Figure 5.50 Map of Uxmal in the project GIS, adapted from Pollock (1980) and Graham (1992). Landsat TM courtesy of NASA.

more extensive, is considerably less detailed than Morley's (1946) a map that is routinely cited. To date, the most detailed map of the central precinct of Uxmal was published by Graham (1992). Elements from the Tulane, Morley, and Graham maps were incorporated into the project GIS (Figure 5.50) to recover spatial data pertaining to the nature and distribution of water management features. INAH is funding an ongoing

archaeological project including excavation, consolidation and restoration under the direction of Jose Guadalupe Huchim Herrera.

The mapped area of the walled settlement covers an area of 1.28 square kilometers. An additional four or more square kilometers of contiguous settlement most likely exists beyond the walled central precinct. The Tulane map published by Pollock (1980) includes the central precinct and a portion of the periphery. The Tulane map coverage is approximately 4.17 square kilometers. The hydrological adaptive regimen at Uxmal should include moderately active rather than passive strategies to channel, transport, redirect, conserve, and store rainwater for consumption during the driest months of the year as well as archaeological and ethnographic evidence of cave exploitation. As Barrera Rubio (1978) pointed out, the water in these culturally modified lakes is stagnant and they remain dry for a substantial portion of the year. For Barrera Rubio, the water in *aguadas* represented a source of water for construction purposes but not a major source of water for human consumption. In light of the account in the Chilam Balam and problems with water in the peninsula, Barrera Rubio might have a point. However, surface water might have been safer for consumption than water derived from subterranean sources.

In 1996, Winemiller, Cobos, and Ochoa-Rodriguez, established a datum on the upper platform of the Adivino and several benchmarks in peripheral areas of Uxmal for the Uxmal Archaeological Project (Figure 5.51). Although Carlos Perez Alvarez mapped outside the wall over several field seasons, no substantive results of the survey exist in INAH informes or were published as maps. A marked difference exists between settlement density and the complexity of architecture found inside the wall and settlement units found in the periphery. The distinction is repeated in the distribution of *chultunes*. A total of 71 of the 92 *chultunes* located in existing maps or during field survey occur within the 0.476 square kilometer walled central precinct. The calculated *chultun* density inside the wall equals 149.16 per square kilometer, markedly higher than the 102.96 per square kilometer at Sayil. Sayil has fewer *aguadas* than Uxmal. If the area of coverage is extended to include all 12 *aguadas*, the *chultun* density is 77.98 per square kilometer. Clearly the density of both architecture (population) and *chultunes* seems to experience a fall off beyond the walled central precinct. The decline is related to settlement density and occurs in the periphery at many sites as



Figure 5.51 Winemiller at Uxmal datum on the upper platform of the Adivino.

evidenced by increased frequencies of open spaces between settlement clusters in the periphery as size and frequency of architectural groups present decreases. Essentially, measures of *chultun* or well frequency establish settlement density as well.

During fieldwork at Uxmal, a systematic survey was conducted of areas within a 150-meter perimeter of five of the 12 *aguadas* reported in Huchim Herrera's 1991 B.A. thesis. Stephens suggested that *buktes*, bell-shaped excavations into

the base of *aguadas*, were constructed to take advantage of water trapped in saturated clays and soils beneath the stone or impermeable-clay lining the *aguadas*. Huchim Herrera (1991) excavated a *bukte* in *Aguada Chen-Chan* at Uxmal, Yucatan. The innovation permitted ground water to filter through permeable walls into a cavity, effectively extending the depth of *aguadas* to the level of the base of the *bukte*. 1991:130-42.

Evidence of significant architectural groups situated within the survey zone around the five *aguadas* was not found. The information collected at Uxmal including, high *chultun* densities relative to other sites in the region, a dearth of settlement remains on or near *aguada* rims, and the architectural center of mass existing outside the zone containing the major *aguadas* appears to support Barrera Rubio's suggestion that the *aguadas* of Uxmal might not have functioned as primary sources of water for human consumption. Seemingly, the ancient inhabitants relied on *chultunes* for a portion of the year. The ancient Maya invested a considerable amount of energy modifying the naturally formed depressions as evidenced by clay liners, *buktes*, well shafts, and stone rims. They must have used *aguadas* as sources of water as well as other, as yet undefined, functions for a portion of the year.

Barrera Rubio (1978) cited the association of *chultunes* with high status residential complexes mostly inside the wall as evidence of "elite control of water." A correlation between elaborate *chultunes* as evidenced by cut stone necks, embossed representations of frogs, turtles and Ceiba trees placed on interior finely plastered surfaces and vaulted architecture considered to represent elite space appears to exist. Figure 5.52 illustrates representations of frogs, turtles (lower right) and Ceiba trees (lower left) inside a *chultun* located on a platform supporting vaulted architecture just inside the southeastern corner of the wall approximately 80 meters southwest of the Temple of the Old Lady. Similar plaster iconography was found inside *chultunes* at Sayil and Nohpat as well. During fieldwork at Uxmal, a systematic survey was accomplished in an area measuring approximately 0.25 square kilometers outside the walled central precinct. Two residential groups containing non-vaulted architecture are located beyond the eastern wall, 400 meters east of the Adivino, the tallest pyramid at Uxmal. Two *chultunes* were noted in one group and three in another. Calculated *chultun* density for the contiguous settlement area defining these groups totaled 94.34 per square kilometer. This figure is close to the 94.64 per square kilometer reported earlier for Sayil. The striking similarity



Figure 5.52 Example of an elaborate *chultun* at Uxmal.

between ratios for Uxmal and Sayil suggests that detailed settlement survey can be used to develop frequencies that represent predictable relationships that existed between various water management features, specific physical characteristics, and architectural density.

Research at Uxmal did not reveal evidence to suggest that elite power at the site was based upon the management of water resources. Evidence for elite management would have included

walled in *aguadas* or *chultunes* or elite spatial preference for *aguadas*. Unlike Becan where an *aguada* was part of the moat bounded central precinct, the walled central precinct at Uxmal effectively separated inhabitants from water stored in the surrounding *aguadas*. The spatial distribution and frequency of *chultunes* at the site provides additional insight into the relationship between water and power. The presence of *chultunes* was apparently not correlated with status, but additional data from peripheral areas are needed to be certain. Moreover, similarities between density of water features per square kilometer inside and outside the walled central precinct and intersite similarities confirm the notion that *chultunes* were the essential adaptive strategy in a this portion of the district.

Rio Bec District

Becan

Becan, a first order site (Garza and Kurjack 1980), is located in the eastern portion of the modern State of Campeche, Yucatán, Mexico. The central precinct, bounded on all sides by a moat, covers 0.26 square kilometers. Becan is located at 16Q 239501mE, 2049231mN UTM, 18° 31' 03.232" North, 89° 28' 02.700" West in the eastern portion of Wilson's (1980) Rio Bec District

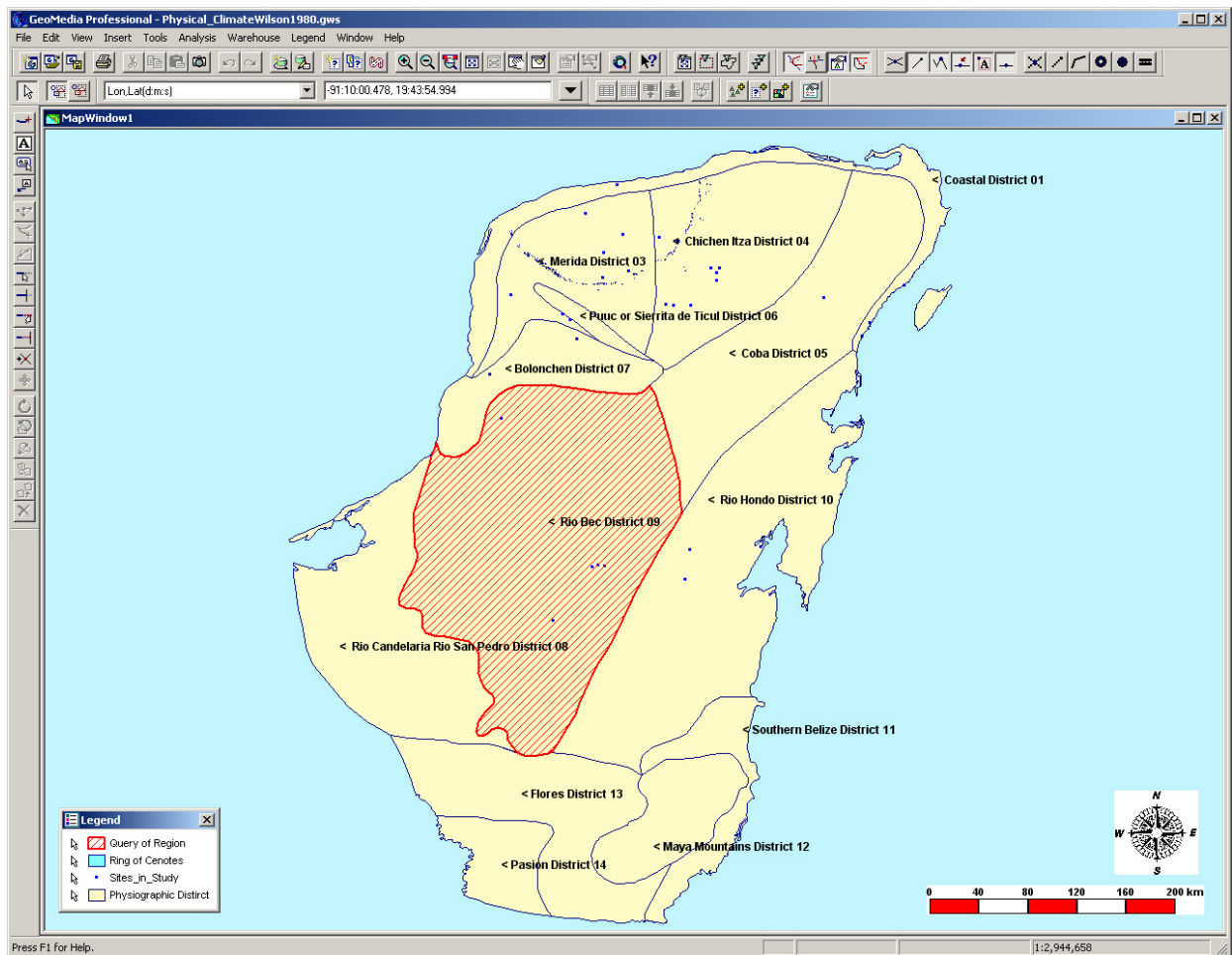


Figure 5.53 Wilson's Rio Bec District in the project GIS.

(Figure 5.53), an area fittingly characterized as tropical savanna and rainy. The immediate area contains broad, conical hills, high linear ridges, intermittent lakes, and generally poorly developed drainage. The total mapped portions of Becan including settlement units outside the central precinct cover 4.018 square kilometers. Today, a portion of this area consists of *bajos* or seasonally flooded grassy savannas.

Ruppert and Denison, Jr. (1943) described the site core as compact with three main groups. The site is located beyond the coverage area of the three subsurface hydrology maps obtained from Mexico's National Water Commission, but is 31 kilometers west of the 100 meter cline on the Quintana Roo map (Dirección General de Administración y Control de Sistemas Hidrológicos Dirección de Aguas Subterráneas 1989b). Depth to static water in the Rio Bec District ranges from less than 30 meters in the extreme northeastern section to more than 100 meters in areas where ridges reach 275 meters in height, suggesting wells were not an available or desirable adaptive option for the inhabitants at Becan. Instead, areas providing poor drainage required modifications to channel water away from potential settlement areas. Physical conditions in the area predict *aguadas* and *chultunes* at Becan.

Carr and Hazard (1961) suggested natural terrain was the most significant locational determinant in ancient times. Like other sites surveyed for this paper, the spatial distribution of Becan's settlement units by and large appears to be a function of a particular physical environment consisting of a series of low ridges interrupted by bajos and seasonally flooded grassy savannas. This pattern occurs at Dzibanché and Kohunlich as well. As evidenced by higher frequencies of

structures on ridge tops or artificially elevated areas, the ancient inhabitants preferred to avoid the hazards associated with settling in low-lying areas that were in the past as today prone to seasonal flooding.

Ruppert and Denison, Jr. (1943) were the first archaeologists to survey and map the area inside the artificially constructed moat that surrounds the central precinct. Several scholars focused their efforts on Becan; Webster (1976a) investigated the function of the moat; Ball (1977) established a ceramic sequence and attempted to develop a better understanding of the Rio Bec region; Potter (1977) attempted to clarify and demonstrate consistency of Rio Bec-Chenes architectural style in the central Yucatán sub-region; Thomas, Jr. (1981) completed a settlement pattern study of the Becan area including the sites of Chicana and Xpuhil; Hohmann (1989) described the form and function of Structure IV; and Bueno Cano (1999), completed a survey of archaeology in the Rio Bec region. Two maps, the Carnegie map produced by Ruppert and Denison (1943) and the Settlement Pattern Map of Becan by Thomas, Jr. (Jr. 1981) were incorporated into the project GIS.

Becan is best known for the moat, *moat* in Spanish, bounding the site core (Figure 5.54). The moat completely surrounds the central precinct limiting ingress to the site to

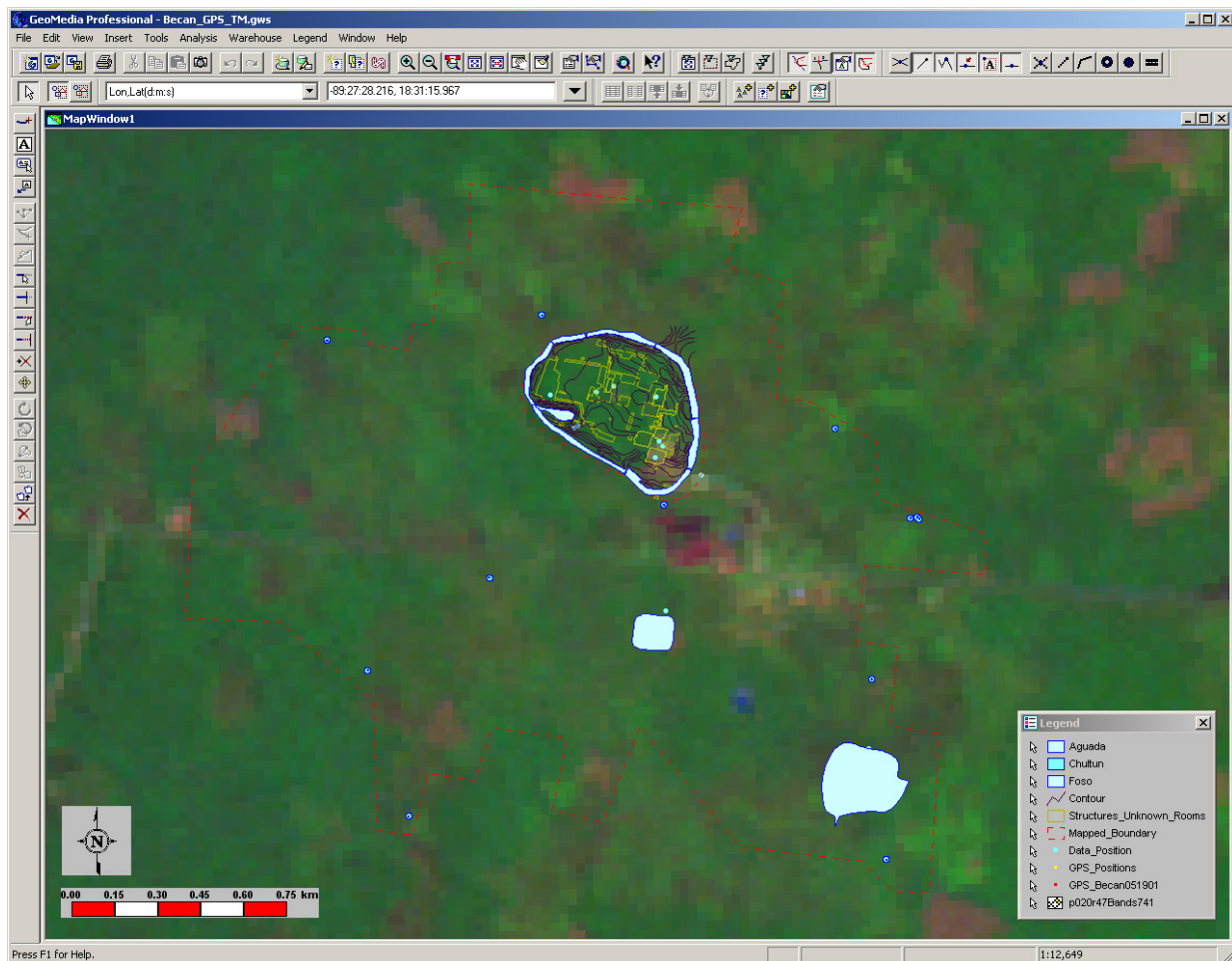


Figure 5.54 Site of Becan in project GIS over Landsat TM. Landsat TM courtesy of NASA.

seven bridges leading into the center from radiating causeways. A similar moat-like feature, the Tikal Ditch, is located 4.5 kilometers north of the central precinct at Tikal, Guatemala (Puleston and Callender Jr. 1967; Webster 1976a). The moat is 1,890 meters in length, varies from three to 25 meters in width and two to four meters in depth (Webster 1976a). Although, function of the moat is debated, a generally accepted notion

exists that explains the moat in terms of defensive works. For all intents and purposes, the moat (Figure 5.55) represents the most complex hydrological accomplishment surveyed at Becan. Webster (1976a) placed the major construction of the moat to between A.D. 100 and 450. There are several spatial similarities between the bounded settlement organization of Becan and ancient Shang civilization cities of China dating from 2000 to 1027 B.C. For example, walled enclosures served primarily as an elite center, clusters of lower-status residential units and workshops surrounded the elite centers, abundant elite goods were found within central precincts and are noticeably absent beyond the enclosed area suggesting unequal distribution of certain goods (Scarre and Fagan 2003). Additional discussion of ancient city-states in China is found in (Scarre and Fagan 2003; Yates 1997).

According to INAH guards at Becan, the moat never contains water. This Becan area receives between 1000 and 2000 millimeters of rain annually (INEGI 2001a, b, c). Monthly rainfall varies between 25 to 50 millimeters per month during the driest period from November to April and 100 to 200 millimeters per month at the height of the season (Vokes and Vokes 1983; West 1964; Wilson 1980). During survey at Becan in



Figure 5.55 Moat "*foso*" at Becan, view toward the south.

late May and mid-August, the middle of the rainy season, the moat was dry. Sections of nearby low-lying areas were either saturated or flooded. *Aguada Carmelita* 277.9 meters south of the central precinct was filled to capacity (Figure 5.56).

Webster suggested that the moat was filled with drainage from a large lake that once existed to the north of the site. Today, the area where the lake existed is a heterogeneous region containing sections of semi-annually inundated grassy savanna



Figure 5.56 *Aguada Carmelita* at Becan.

interspersed with expanses of wooded bajo. I argue that during expansion of the site, soil excavated during construction of the moat provided fill materials essential to elevate the central precinct above surrounding areas prone to seasonal flooding. During survey most of the area surrounding the site was partially inundated.

Three *aguadas* occur within a radius of 1.5 kilometers of the site core. This area contained the largest portion of the

architecture of Becan. Beyond 1.5 to 1.8 kilometers the distribution of settlement units makes a transition from high density to a pattern resembling Bullard's (1960) northeastern Peten model known as clustered dispersed. Natural terrain forms all the *aguadas* in the area. The smallest *aguada* was found within the area bounded by the moat south of Structure 8. When filled to capacity, this *aguada* would have held approximately 900,423 liters of water. Assuming no recharge, evaporation, or water loss through seepage, this feature could have supported a population of 514 persons at a consumption rate of 4.8 liters of water per day, a rate adopted from McAnany (1990) that reflects double the generally accepted minimal human water consumption of 2.4 liters per day cited in the World Book Encyclopedia.

The second *aguada*, known as *Aguada Carmelita*, appears to be linked to the central precinct by a causeway (Webster 1976a). The culturally modified natural depression lies 675 meters south of site. Ruppert and Denson Jr. (1943) stationed their base camp at *Aguada Carmelita* during the spring and summer of 1934. A third *aguada*, the largest in the Becan area, is situated 1.37 kilometers southeast of the center of the administrative core. Assuming *aguadas* were sources of drinking water, the three *aguadas* could support the annual needs of

7,188 persons (Bullard 1960). Thomas, Jr. (1981) estimated population in the immediate Becan area from the Late Preclassic Period (250 B.C.) to Early Post Classic (A.D. 1050 - 1150) to have averaged 1384 persons, peaking at 2862 during the Bejuco Phase (A.D. 650 - 700) and reaching its lowest level, 907 persons, during the Chacsik Phase (A.D. 250 - 350). Assuming *chultunes* functioned to capture and store water for human consumption, the twelve *chultunes* in the Becan settlement area would have provided water to an additional 180 to 360 persons based upon McAnany's (1990) estimates for *chultun* support capacity. Contrasting the Uxmal pattern where a walled central precinct produced the highest density of *chultunes*, Becan's periphery has more *chultunes* and a greater density.

Thomas, Jr. (1981) suggested the Becan *chultunes* follow no clear distribution pattern with respect to their association with domestic architectural groups. Moreover, the pits were located on the periphery of settlement zones adjacent to seasonally flooded *bajos*. The project GIS revealed that 12 of the 15 *chultunes* known to exist in the Becan area are somewhat evenly distributed approximately 0.5 kilometers apart within a radius of 1.7 kilometers from the site core (Figure 5.57). This distribution might follow a modal or maximum transport distance of one-half kilometer. If this is the case, the assumption also

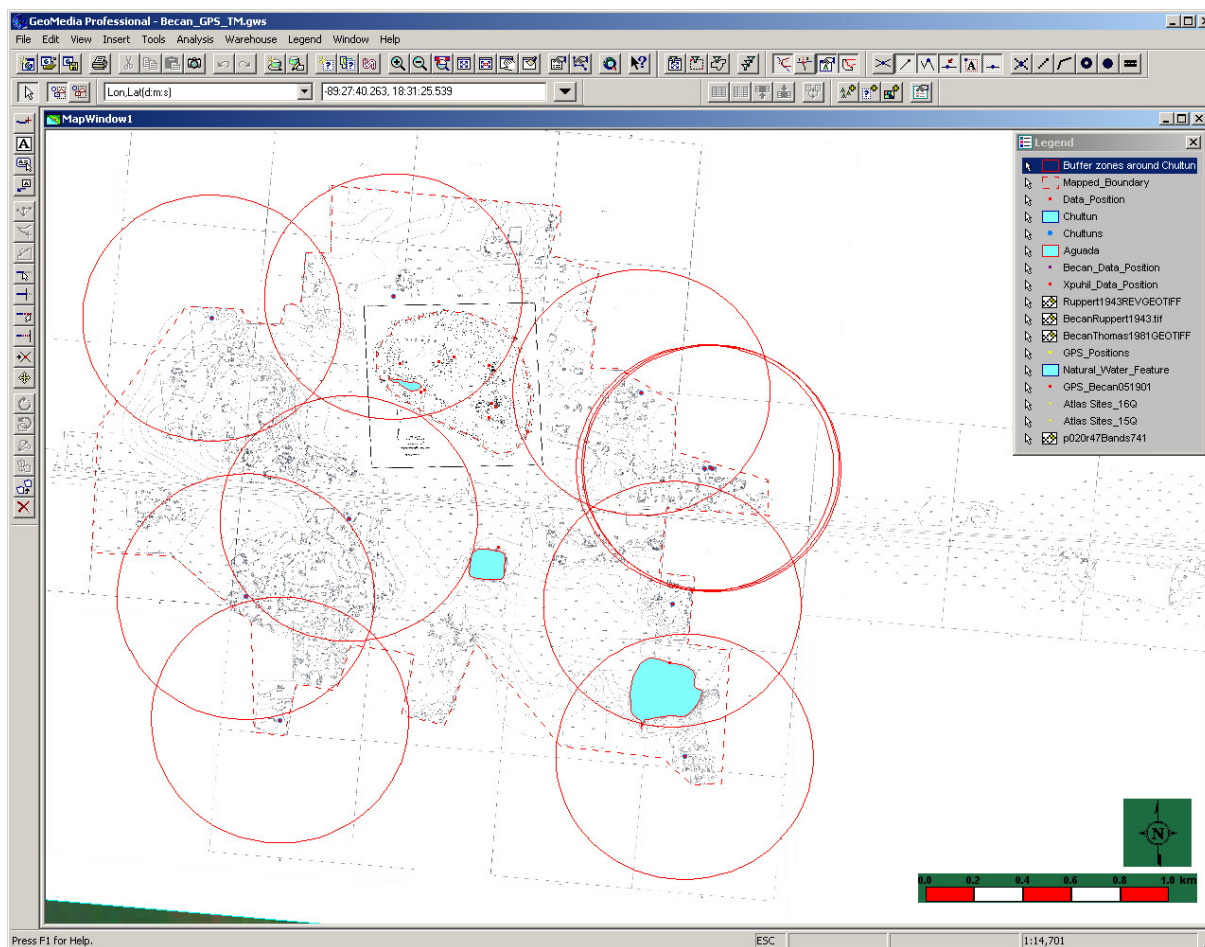


Figure 5.57 500-meter buffer zones around the *chultunes* of Becan. Landsat TM courtesy of NASA.

could be advanced that *chultunes* were common property and accessible by all inhabitants at the site. This is not difficult to imagine considering that the spatial distribution of domestic space in rural more traditional modern Maya villages is often structured around kinship ties, as Virginia Ochoa-Winemiller (personal communication 2003) discovered while carrying out ethnographic fieldwork the Yucatán. In one instance, Structure 6-H-16, three *chultunes* are clustered

within 30-meters of each other. At the site of Chicana, located a few kilometers to the southwest of Becan, two *chultunes* were found spaced 15-meters apart 35-meters northeast of a major group containing vaulted architecture.

Chultunes in the Becan area are not as elaborate as their counterparts from other sites in the northern peninsula. This might be explained by context. I found 15 *chultunes* in the Becan settlement area including two at Chicana and one in a group of scattered platforms and structures 1.74 kilometers to the west-northwest of Chicana. One *chultun* is on a platform having the remains of vaulted architecture, two lie under the remains of an unvaulted structure, and twelve are located in off platform contexts, many on the edge of *bajos*. Only one *chultun* had a plaster lining. The lined *chultun* at Chicana was refurbished in modern times and might have been modified during the Colonial Period. This is one of a few *chultunes* observed that held water. Most of Becan's *chultunes* are simple pits or elongated chambers excavated into caprock or bedrock. Many had a limestone capstone. The Becan *chultunes* have circular mouths averaging 50-centimeters in diameter. Interestingly, the 50 and 70-centimeter average measurements represent two of several standard-size opening and column dimensions found throughout the peninsula. Fifty-centimeters is near the forearm to middle-

fingertip length of an average man and also close to a cubit, which measures approximately 45.7 centimeters. Larger *chultun* mouths and columns seem to cluster around an average of 70-centimeters in diameter. This measurement is close to the shoulder to middle-fingertip length of an average adult male.

If the difference noted between Becan *chultunes* and others observed throughout the peninsula is significant, the question of function seems unavoidable. As mentioned earlier, certain excavated pits often referred to as *chultunes* provided materials for construction of platforms and architecture. There is sufficient variation in form to argue that some of the *chultunes* at Becan might not have functioned as water storage chambers. Instead, these features might represent dry or semi-dry storage pits, provisional burial chambers, materials extraction pits, middens, or snares. Local *aguadas* had sufficient capacity to supply the entire population of Becan and its periphery. The *chultunes* of Becan and the surrounding area including Chicana and Xpuhil were not large-scale public works directed by managerial elites. Instead they appear to be more likely the result of small-scale communal or individual efforts.

Calakmul

The central precinct of Calakmul, the southernmost site in this study, was constructed atop a 2.5 square kilometer dome at approximately 250 meters in elevation. Structure 1 at Calakmul is located at 16Q 202791mE, 2003862mN UTM, 89° 48' 29.565" West, 18° 06' 11.349" North. The mapped portion of the site covers an area measuring 25.976 square kilometers (Figure 5.58). Folan et al. (2001a, b) suggested that the ancient site extended an additional ten kilometers north, south and east of the mapped areas and supported a population approaching or exceeding 50,000 inhabitants. The settlement was occupied from the Middle Preclassic Period through the Late Classic Period (600 B.C. to A.D. 900).

For the purpose of this paper, two key issues need to be addressed. First, was Calakmul or any ancient Maya city, a "state" level society? Secondly, what if any information does the spatial arrangement and nature of hydrological resources and management systems at Calakmul reveal about sources of power and power structure? Folan (1999) citing Flannery (1972) and Marcus (1973, 1976) compared Preclassic Calakmul to El Mirador and Nakbe and suggested Calakmul was a regional state having six major tributary cities, Altamira, La Muñeca, Naachtun, Oxpemul, Sasilha, and Uxul. According to Folan, the

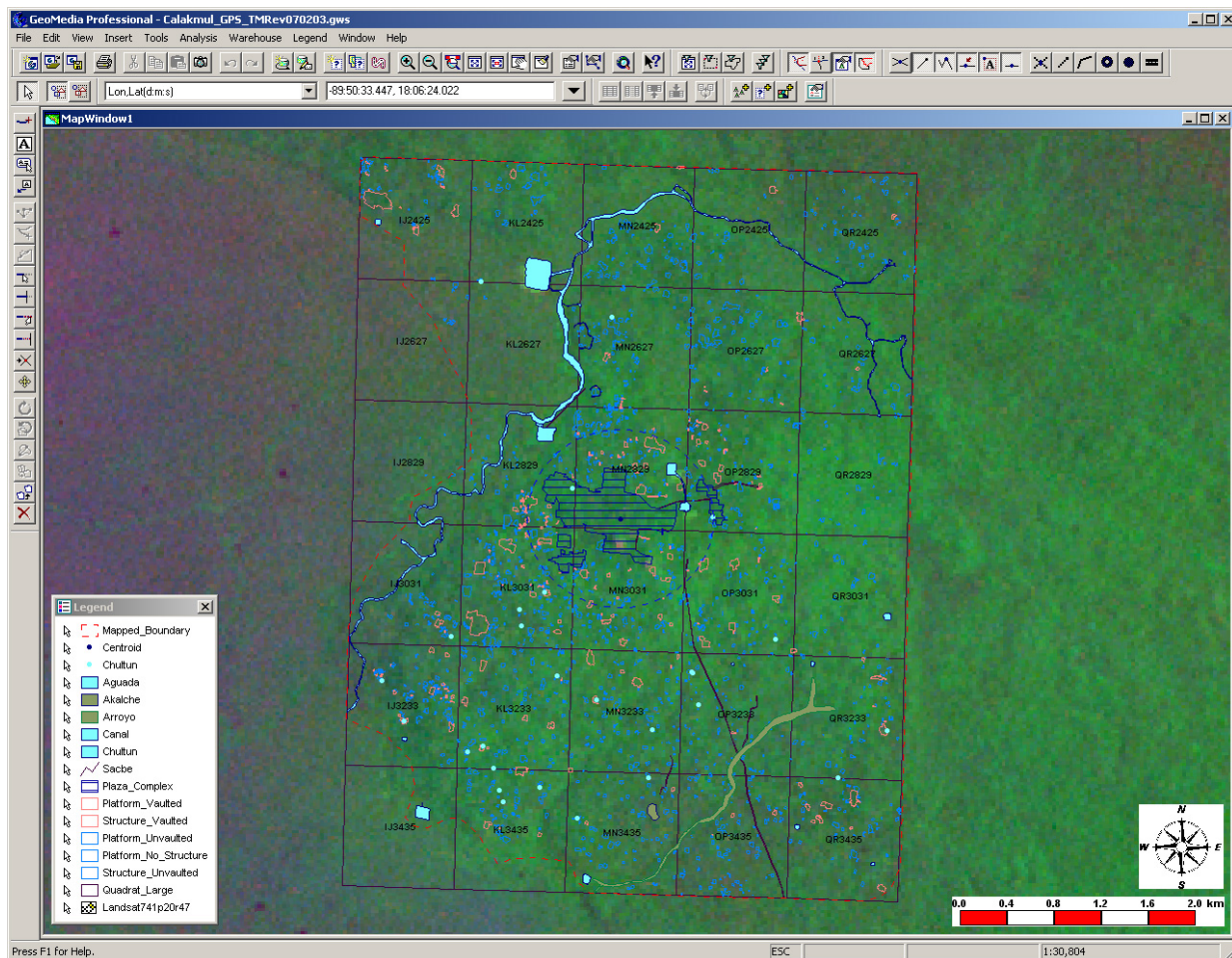


Figure 5.58 Map of Calakmul in the project GIS, adapted from Folan et al. (2001). Landsat TM courtesy of NASA.

six tributaries were spaced equally apart, approximately 35 kilometers from its central precinct in a fashion like Walter Christaller's hexagonal central place model.

Charlton and Nichols (1997) defined minimal criteria for a "small state system." Their list included "...a state system centered in a capital city or town; a small integrated territory or hinterland; a small overall population; political

independence; relative economic self-sufficiency; and perceived ethnic distinctiveness" (Charlton and Nichols 1997). Their criteria are similar to Sjoberg's (1960) description of a preindustrial city in a feudal society. Sjoberg's traits included advanced agricultural technology producing surpluses that support a class of specialists; cultivation of grains; large-scale irrigation works; plows; metallurgy; the wheel and other devices that multiply the production and distribution of agricultural surpluses but are reliant upon human or animal energy; a complex social system; a literate, privileged elite holding political, religious, and economic power, and residing in an urban area; a rigid class distinctions with a clear majority of the population in the lower class; and some form of writing, record-keeping (Sjoberg 1960).

If we consider what is known about ancient Maya society (the information the mapped settlement and material culture provide and avoid speculation about larger boundaries), then data from Calakmul, as well as those from Coba and Edzná, suggest variability and at least one order of magnitude beyond Charlton and Nichols or Sjoberg. Definitions of a state-organized society vary from highly generalized to particular. For some, centralization, hierarchy, form of government, and monopolization of force by a few defines a state. Today, a lack

of consensus can be found sparking controversy over whether or not any Maya polity in the Maya Lowlands achieved state-level status during Prehispanic times. If no states existed in the peninsula, then Wittfogel's ideas must undergo modification to determine whether or not management of water resources sustained the power structure of ancient Maya society rather than contributed to the rise of a pre-industrial state level society.

Carneiro (1981) defined a state as "...a form of politically centralized and stratified society whose governing elites have the power to compel subordinates to pay taxes, render services, and obey the law." Incorporation and subordination of surrounding populations, bureaucracies, and increasing reliance upon tribute to support armies of conquest and expansion could be added to the list of defining traits for a state level society. For the moment, the conditions presented above are sufficient.

Several scholars believe Calakmul was a regional capital (Adams 1986; Flannery 1972; Marcus 1973, 1992a, b). Marcus (1992b) suggested that Calakmul was the northernmost territorial state in a region that included Copán, Palenque, Petexbatún, Tikal, and Yaxchilán and spanned the entire central and southern Peninsula from the modern day State of Chiapas,

Mexico across Guatemala to western Honduras. According to Marcus, inscriptions on stelae erected during the Late Classic Period demonstrate that Calakmul was a major political power in the Maya Lowlands and interacted on various levels with other equally influential polities throughout the region. For example, in A.D. 562 Calakmul forged an alliance with the rulers of Caracol, a site located near the western border of Belize, to wage war against Tikal.

Calakmul is situated approximately 25-kilometers north of the border between Mexico and Guatemala in the modern State of Campeche, Mexico. This area is in the southern third of Wilson's Rio Bec District in an area with some of the highest elevations in the zone. Like Becan, Calakmul lies outside the coverage area for the Quintana Roo or Campeche sub-surface hydrological maps; however, the site is within 81.5 kilometers of the westernmost isoline on the Quintana Roo map that represents a depth to static of 100 meters. The phreatic in this area is more-than-likely deeper than 100 meters beneath the surface, precluding excavation of wells by the ancient inhabitants. Rainfall averages for Calakmul range between 1200 and 1300 millimeters annually (INEGI 2001c). Vegetation coverage consists primarily of lush high Peten rainforest (Roys 1943). The archaeological zone is located in one of the last

remaining areas in Mexico believed to contain primary growth forest and is currently one of many areas of national focus to preserve natural ecosystems.

Lundell (1933) was the first archaeologist to record the site of Calakmul. The name Calakmul given by Lundell, means "two adjacent pyramids in *Mayan*, *ca* two, *lak* adjacent, and *mul* artificial mound or pyramid (Ruppert and Denison Jr. 1943). Under the direction of Morley, the first of four Carnegie Institution Campeche Expeditions, visited Calakmul from April 3 to 24, 1932. A second expedition lasted from February 28 until May 28, 1933. During the second field expedition the Carnegie group completed survey, mapping and recorded geographic coordinates of the central precinct (Ruppert and Denison Jr. 1943).

Lundell (1933) published the first map of Calakmul in 1933. In 1943, the Carnegie Institution published a map of the central precinct of Calakmul drawn by Bolles with 13 additional maps of other archaeological sites in the region surveyed during the four expeditions undertaken from 1932 to 1938 (Ruppert and Denison Jr. 1943). In 1933, Palacios conducted reconnaissance in the area to verify Carnegie findings. Palacios (1945) published an article about the site. Stromsvick (1937) excavated stratigraphic test pits and completed a study

of *metates* at the site. The Proyecto Calakmul under the direction of Folan and Piña Chán (1983) began mapping the site in 1982. The present map of Calakmul was completed under direction of Jacinto May Hau and represents a total of 87 months of fieldwork beginning in April 1983 and ending in July 1989. A final version of the May-Hau map including internal causeways, structures, *aguadas*, canals and an arroyo was published in 2001 (Folan et al. 2001a, b). The project recorded 13 *aguadas*, one *akalche*, four canals, one arroyo, and 26 *chultunes*. All these features were located either on the ground or on the map. One additional *chultun* was registered as well. Interestingly, this *chultun* is one of two situated within the plaza complex in the central precinct.

In 1985, Dominguez Carrasco (1985) excavated six canals, three *aguadas*, one dam-like feature, one elevated area, and two *akalchés*. Zapata Castorena (1985) excavated five of the Calakmul *chultunes* and published her informe. The *chultunes* Zapata Castorena excavated are similar to the Becan *chultunes* discussed above.

Several *chultunes* at Calakmul and Becan closely resemble *sascab*-pits documented previously by Winemiller (1997) at Chichén Itzá. *Sascab*-pits are unplastered and excavated into a

permeable layer of *sascab* rendering the pit unsuitable for retaining water for any measurable length of time.

If morphological similarity is to any extent indicative of functional equivalence, then some of these pits at Calakmul and Becan might have been used for the extraction of *sascab* for mortar. Uncertainty regarding *chultun* function, calls into question a common practice in Maya studies of referring to subterranean pits, regardless of their structure or context, as *chultunes*. The routine practice by Geographers and archaeologists to label subterranean pits having round openings " *chultunes*" is problematic. The term *chultun* is most often considered synonymous with water storage, or if a Puleston adherent, storage of foodstuffs. Not all pits in the ground had the potential to store water or food. Moreover, examples of use or reuse of both plastered and unplastered *chultunes* or cisterns for burials can be found in the literature (Coyoc Ramirez 1992, 1994; Folan et al. 2001a, b; Mercer 1975; Thompson 1897b; Tiesler Blos, Dominguez Carrasco and Folan 1999; Zapata Castorena 1985). Both the ancient and modern Maya were and continue to be masters of reuse and adept in the art of realizing a multifunctional purpose for countless items in their inventory of material culture. For the purpose of this study, all *chultunes* were included in calculations. The

majority of *chultunes* observed did not appear to have required direct involvement of a managerial elite for construction or maintenance. Most of them likely represent individual or small-scale community endeavors.

To facilitate analysis of the data from Calakmul, I modified and used William Folan's six classes of settlement units, including platforms supporting at least one vaulted structure, platforms supporting only unvaulted structures, platforms having no evidence of structures, solitary unvaulted structures on the ground, solitary vaulted structures on the ground, and plaza complexes that include a variety of monumental architecture, purposely avoiding inferences about function. Four additional architectural types at Calakmul, 42 altars, 39 apsidal structures, 119 stelae, and 114 variable-sized round structures were not included as separate classes of settlement units or quantitatively in the following analysis. A total of 90.62 percent of the architecture at Calakmul is unvaulted. Vaulted structures account for 9.19 percent of the architecture. The architecture in the central plaza represents the balance.

Three of the 13 *aguadas* encircle the central precinct. One *aguada* is situated approximately 0.30 kilometers northwest of the edge of a section of the site with a concentration of

varied types of architecture including the monumental structures that make up the central precinct. Two *aguadas* in this portion of the site are connected to a large canal that encircles most of the settlement from its east northeastern edge to the south southwestern periphery where the canal meanders through a large bajo that surrounds most of the site. The canal system might have functioned as much to drain the bajo and for retention as it did to channel water. Remains of platforms and structures are found along natural ridges as well as the level of the canal. No evidence of architectural remains exists on either side of the canal within a buffer zone measuring 0.25 kilometers in the northern, eastern, and southern quadrates. The majority of architectural remains located nearest the canal such as basal platforms for unvaulted structures, platforms having no visible superstructures and solitary unvaulted structures constructed on the ground, represent architecture normally associated with lower levels of the social strata. This buffer zone might indicate a form of hazard avoidance.

Three *aguadas* surround the central precinct. Folan et al. (2001a, b) defined a four-type system based upon context that includes *Aguadas Grandes de Tipo Público* (large size public), *Aguadas Medianas de Tipo Público* (medium size public), *Aguadas*

Pequeñas de Tipo Público (small size public), and *Aguadas vecindales* (neighborhood *aguadas*). Two of the three *aguadas* near the central precinct are considered *vecindales* and the third *grande*. Structure 2 in the central precinct dates from the Late Preclassic through Late Classic Period (Folan et al. 2001a, b) suggesting the geography in the core represents early settlement. The central precinct is not situated on the highest terrain, ruling out elevation as the most important locational consideration. The presence of three *aguadas* in the area suggests there might have been a preference for location near depressions that naturally retained water. Like the *aguadas* observed at Becan, *aguadas* at Calakmul appear to be a combination of natural relief and human modifications (Figure 5.59).

A 260-meter canal links two of the three *aguadas* located near the central precinct. This canal courses southeast from the northernmost *aguada* for approximately 120 meters avoiding a platform supporting several vaulted, unvaulted and round structures situated just off the northeastern edge of the central plaza before it turns abruptly south. Dominguez Carrasco (1985) excavated a bridge at the point where a causeway crosses this canal (Folan et al. 2001a, b). Two additional canals are found north of the Central Precinct.



Figure 5.59 Aguada at Calakmul.

These inverse C-shaped features resembling oxbow lakes are narrow in width and encircle small architectural groups on three sides (Figure 5.60). Both groups are situated in low lying areas that would have been flood prone, leading me to assume that drainage was a principal function.

Although different in scale and context, the canals demonstrate that the ancient inhabitants of Calakmul, like those of Edzná (Matheny et al. 1983) and Tikal (Scarborough

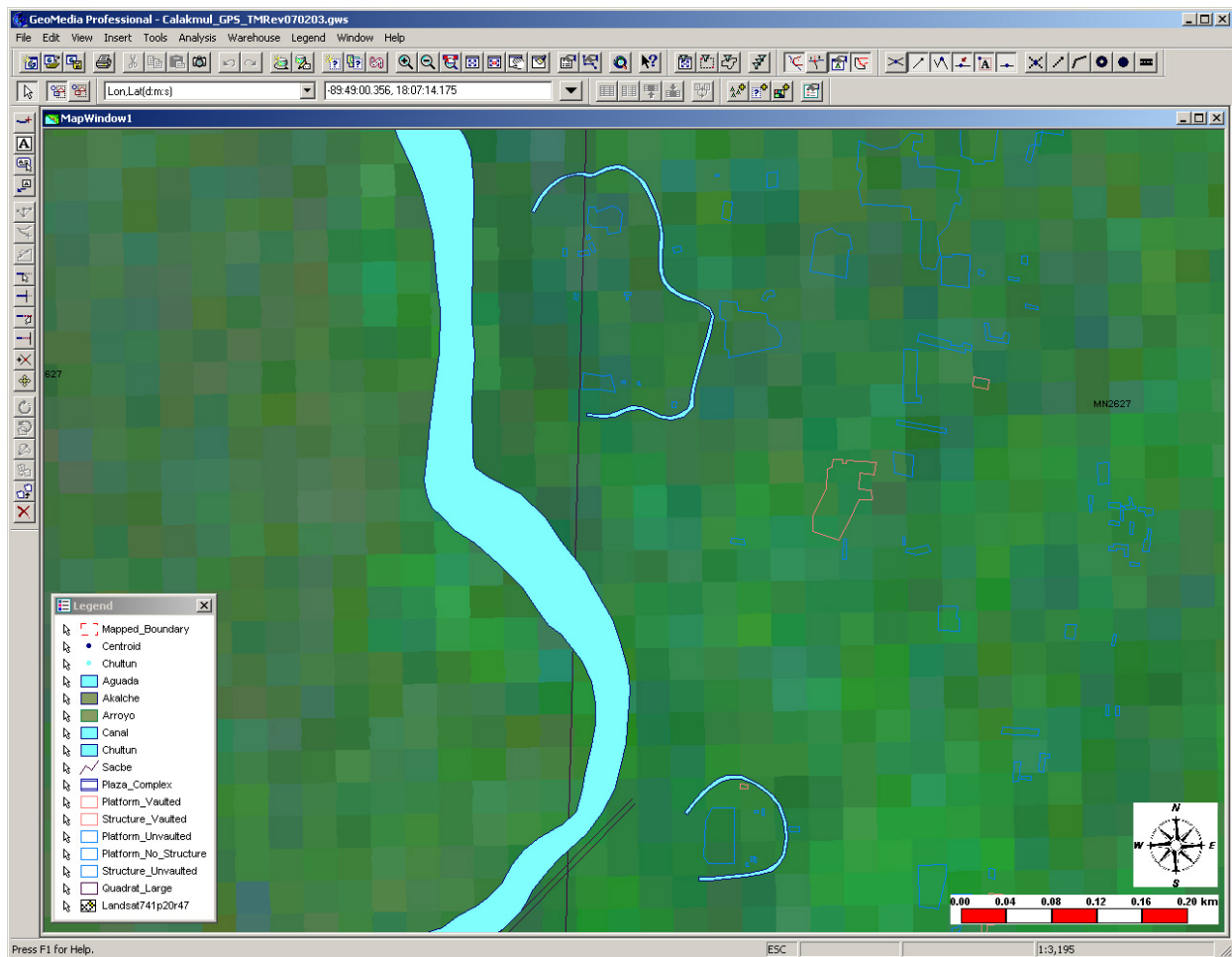


Figure 5.60 Two architectural groups with C-shaped canals on eastern edge of *bajo* at Calakmul. Landsat TM courtesy of NASA.

1993b) were resourceful engineers capable of modifying naturally formed hydrological features to accommodate the needs of large populations.

The established site grid was used to analyze the distribution of water features by quadrat. The following section provides descriptive statistics based upon this distribution. *Chultunes* at Calakmul cluster in the southern

portion of the site. The remains of two *chultunes* were discovered inside the central precinct, one was within the walled space. There are three *chultunes* on platforms having at least one vaulted structure, one on a platform supporting unvaulted structures, one on a platform with no evidence of structures, and 20 are off platform, see Figure 5.58. A total of 14 out of 30 one-square kilometer quadrats in the Folan et al. (2001a) map contain one or more *chultunes*. Eleven quadrats contain one or more *aguadas*. Two canals flow through nine quadrats and the arroyo courses through four quadrats. There are three quadrats in the map that have evidence of settlement units but no visible sources of water or water storage features. A total of 232 of the 2504 architectural features mapped in 26 of the 30 map grids are vaulted structures or platforms containing at least one vaulted structure. The distribution of vaulted and nonvaulted features at the site appears to be nonrandom and a relationship seems to exist between architectural feature class and water resources.

Although used interchangeably, the terms "pattern" and "dispersion" in analyses of point patterns have quite different meanings. I adopt definitions employed by Dacey (1973), Sibley (1976), and Shaw and Wheeler (1994). Thus, "pattern" refers to distances between and arrangement of points in space, whereas

dispersion means the areal extent of a collection of points" (Dacey 1973; Shaw and Wheeler 1994; Sibley 1976).

Variance-mean ratios (VMR) and contingency tables are two statistics geographers can employ to characterize point patterns and cause-effect relationships between sets of variables. These statistics were employed to establish whether or not visual patterns in the distribution of vaulted and unvaulted architecture represent more than random incidences. The variance-mean ratio, VMR for vaulted and unvaulted features in the 26 sample quadrats mentioned above is 10.99 and 24.51 respectively. Corresponding large Chi Square statistics for each VMR produce smaller than 0.05 p-values suggesting the distribution of these features at Calakmul is nonrandom, tending toward clustered (McGrew Jr. and Monroe 2000; Shaw and Wheeler 1994).

The remains of 27 *chultunes* at Calakmul are distributed in 14 quadrats. There are six quadrats with one *chultun*, four quadrats with two *chultunes*, three quadrats with three *chultunes* and one quadrat with four *chultunes*. The average number of vaulted features per *chultun* in the 14 quadrats is 5.30 and the unvaulted features average 50.00 per *chultun*. Vaulted features average 10.21 per quadrat in the 14 quadrats where the remains of *chultunes* were found. Unvaulted features

average 96.46 features per quadrat in the same area. In quadrates where *chultunes* were not present the averages are 7.42 for vaulted and 76.83 for unvaulted respectively. Vaulted features averaged 10.40 and unvaulted 78 features in quadrats that contained *aguadas*. In quadrats in the sample of 26 having no *aguadas* or *chultunes*, the averages are 4.88 vaulted features and 75.00 unvaulted features per quadrat. Clearly, there is a noticeable decline in the average for vaulted features while the average count of unvaulted features remain relatively stable. Considering the generally accepted relationship between vaulted architecture and status, the statistics suggest that a segment of society, at the very least, preferred to locate within an as yet undetermined distance of water, might have had preferential access to water resources, or had sufficient resources to insure a measure of water storage capability throughout the year.

Inferences can be made about human behavior as indicated by the statistics but the cause of distributions remains unknown. The pattern might be the result of social or physical factors, reflect the result of an unknown sequence of events, or point toward a complex set of factors that impacted human locational decisions. At present, the information is insufficient to be certain. As evidenced by the location of the

largest canal along the rim of the surrounding bajo the physical environment at Calakmul played a role in settlement formation and transformations through time.

The constructed landscape of Calakmul suggests that water management was a concern of the ancient inhabitants. Areas having rich soils along the fringes of bajos might have been the likely spaces to settle for early residents of the area. These areas would have been nearest to standing water and home to a diversity of fauna and flora. Initial efforts to make these low-lying areas suitable for agriculture would have resulted in water retention features such as the *aguadas* and canals still visible in the cultural landscape today.

Edzná

Edzná is a first order settlement located approximately 43 kilometers southeast of Campeche, the capitol of the modern-day State of Campeche. Structure 19, the Acropolis, is located in the central precinct of the site at 15Q 790632mE, 2169239mN UTM, 19° 35' 49.039" North, 90° 13' 46.066" West. The densest portion of the settlement covers an area measuring approximately 3.5 square kilometers. If the area is expanded to the extent of the known canal system, the site covers 9.976 square kilometers. Aquifer depths near Edzná average between 30 to 50 meters below the ground surface (Dirección General de

Administracion y Control de Sistemas Hidrologicos Direccion de Aguas Subterraneas 1989b). Edzná is near the northwestern extent of the Chenes zone, named for numerous shallow wells in the area. As Eugene Wilson points out, the name Chenes does not reflect a true physical reality. The actual ratio of wells to total area in the zone known as the Chenes is very low Wilson (1980:17).

George Andrews (1968, 1969), University of Oregon, accomplished an extensive survey of Edzná beginning in 1968, resulting in a map that remains in use today (Figure 5.61). Matheny (1983) investigated hydraulic management at Edzná and published findings in 1983. Piña Chan (1985, 1993, 1996) wrote several manuscripts and produced a map of the site in 1996. Since 1998, archaeologist Benavides C., M.A. has directed a continuing project of survey, consolidation, and restoration (Proyecto Edzná). For a thorough list of prior archaeological research at Edzná and citations, consult "Antecedentes" in Benavides C. (1999), and Millet Cámara (2001).

Matheny (1978) noted 471 known house mounds (over 200 associated with canals), 100 public buildings, 31 canals, 84 reservoirs, a "fortress" surrounded by a moat, 18 rock quarries, 12 *chultunes*, and no wells. Andrews (1969) reported

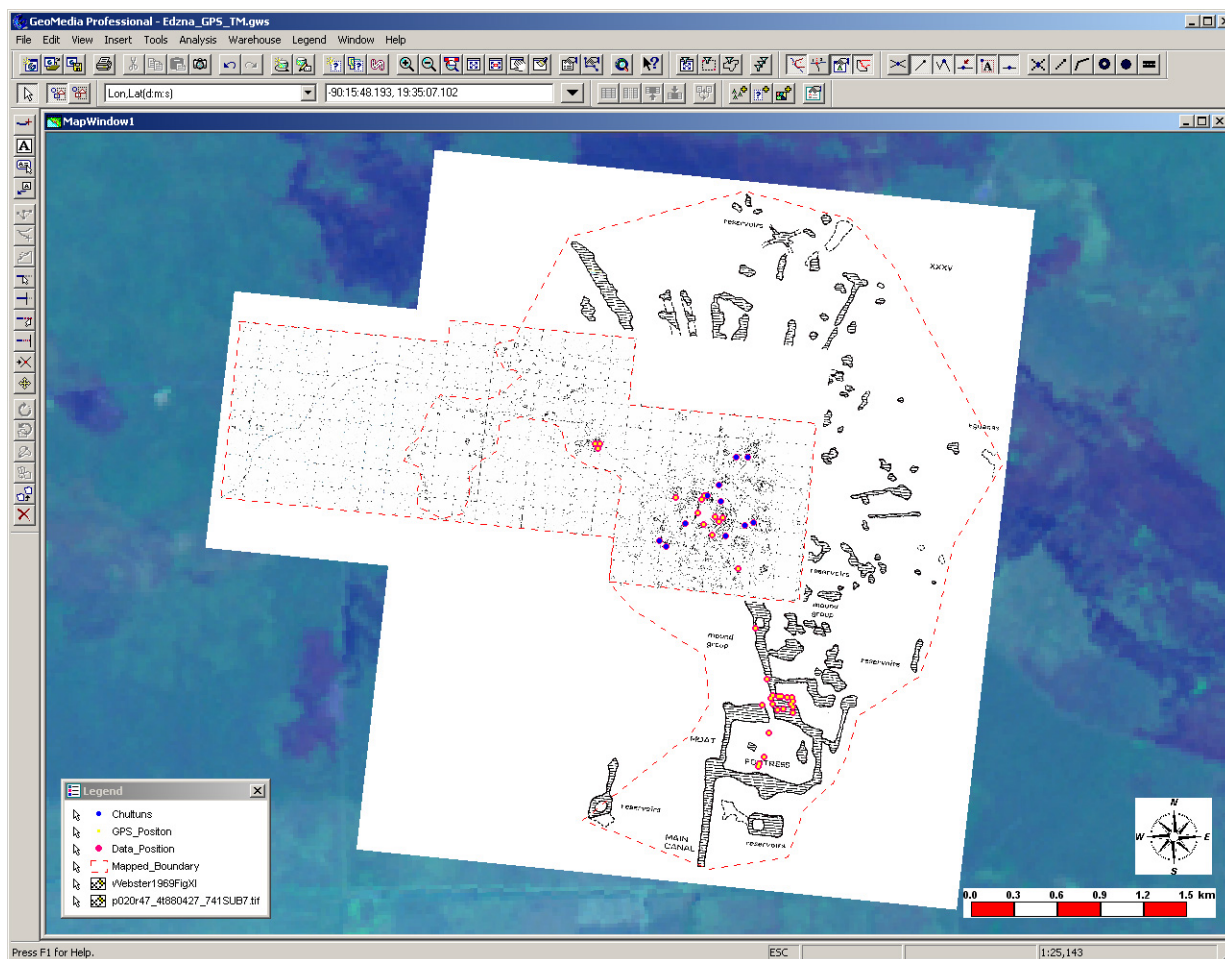


Figure 5.61 Map of Edzná in the project GIS, adapted from Andrews (1969) and Matheny (1978). Landsat TM courtesy of NASA.

11 *chultunes* at the site, all within the ceremonial complex in (Puleston 1965).

During field survey, 11 *chultunes* were found. One of the *chultunes* observed is not listed on the Andrews map. The calculated density of the 11 *chultunes* occurring in the most densely populated area is 3.143 per square kilometer. If Matheny's (1978) count of 12 is used, *chultun* density per square kilometer increases to 3.714. Evidence of wells was not

found during survey and none are mentioned in the literature. This suggests natural and culturally modified or constructed surface features provided sufficient quantities of water to sustain populations inhabiting the settlement and the environmental profile is not favorable for excavation of wells. Local workers knew the location of several additional *chultunes* in the area but unfortunately; the insufficient time and resources were available to reconnoiter the site periphery.

Ceramic evidence collected by others indicates an occupation of Edzná lasting from 600 B.C. to A.D. 900 (Andrews 1969). Collections from this project concur with these dates. The earliest settlers in the area were likely attracted to the numerous naturally formed *aguadas*. Joventud Red: Joventud ceramics belonging to the Nabanche - Mamon Ceramic Complex were discovered along the edge of a platform adjacent to an *aguada* in a section of the site known as the Fortress. Nabanche - Mamon pottery dates to a period between 600 and 300 B.C. Interestingly, Navula Unslipped: Navula, a Muralla Complex Ceramic (A.D. 800 to 950) was recovered from the Fortress Group as well, suggesting that the area was continuously occupied for most of the sites history. Joventud Red was also collected around *Chultun* Number 3 situated five meters south of Structure 4, in Quad W8 (Andrews 1968). In both instances the Joventud

Red was discovered in areas near or adjacent to *aguadas*. More recent ceramics were collected from natural depressions. The spatial pattern of early ceramics suggests that proximity and opportune access to *aguadas* might have been significant considerations in early locational decisions, and in the broadest context, confirm the consequence of the presence or absence and spatial distribution of natural sources of water for settlement location across the peninsula. The earliest ceramics mentioned in the literature are Late Preclassic Period (300 B.C. to A.D. 200) taken from excavations around Structures 8 and 14 in Quad U7 of Andrew's 1968 map (Ojeda Mas 2001). These buildings are located 45 meters south of a natural depression that could have held water during the rainy season.

Hydrological management at Edzná consisted of a complex system of canals (Matheny 1978), possible sediment tanks (Hauck 1973), and *aguadas*. Andrews (1969) argued that the water storage, diversion, and transport system involving several canals and reservoirs was complete by Late Preclassic times, 300 B.C. to A.D. 200. Citing the overall integration of the longest canal, 12 kilometers, into a network of canals, Matheny (1978) argued that the feature was part of a "grand scheme" to create a hydraulic management system wherein canals were precisely aligned with the physical layout of the site.

Like Webster for Becan, Matheny argued that the moat surrounding the architectural group known as the fortress functioned as a defensive barrier. In both instances, an argument could be made that these features were initially constructed to divert water away from inhabited spaces or create dry land for construction of architecture or agricultural purposes. Storage of water for human consumption and agriculture are benefits that could have been derived from these types of features. They might have afforded a measure of protection or enhanced defensibility but do not resemble Old World moats that were components within a defensive systems that contained water bodies, sheer rock walls and few routes of ingress. For Matheny (1978), the hydrological system at Edzná as well as evidence from other sites and regions such as the Tabasco Gulf Plain along the Grijalava and Candelaria Rivers, Isla de Jaina, Santa Rosa Xtampak, and Uxmal provide support of a guarded definition of ancient Maya society as hydraulic during the Preclassic Period. At the very least, the data for Edzná present a strong case for organized management of resources over a large area. While Matheny argued that Edzná's canal system diverted water toward the Central Precinct, Scarborough (1993b) pointed out that the hypothesized Edzná plan is the opposite of well-developed systems elsewhere in the

Lowlands that originated as concave micro-watersheds and ultimately evolved through accretive processes into convex watershed systems used to channel water away from the core similar to the drainage function I propose for the fortress area. Undoubtedly, Edzná's hydrological system is the result of design similar in scope to the cumulative results of architectural development visible at the site today. That the development, construction, and management of hydraulic systems at Edzná supported elite authority remains to be demonstrated.

Rio Hondo District

Dzibanché

The first-ranked site of Dzibanché is situated approximately 51.2 kilometers west northwest of Chetumal, Quintana Roo, Mexico at 16Q 314460mE, 2061734mN UTM, 88° 45' 31.911" West, 18° 38' 18.418" North. Gann (1928) named the site Dzibanché, meaning "writing on wood," referring to a carved wooden lintel in Structure Number VI containing a date of A.D. 618. An ongoing project of exploration, survey, mapping, consolidation and restoration is underway at Dzibanché under the direction of Nalda. For a complete history of work

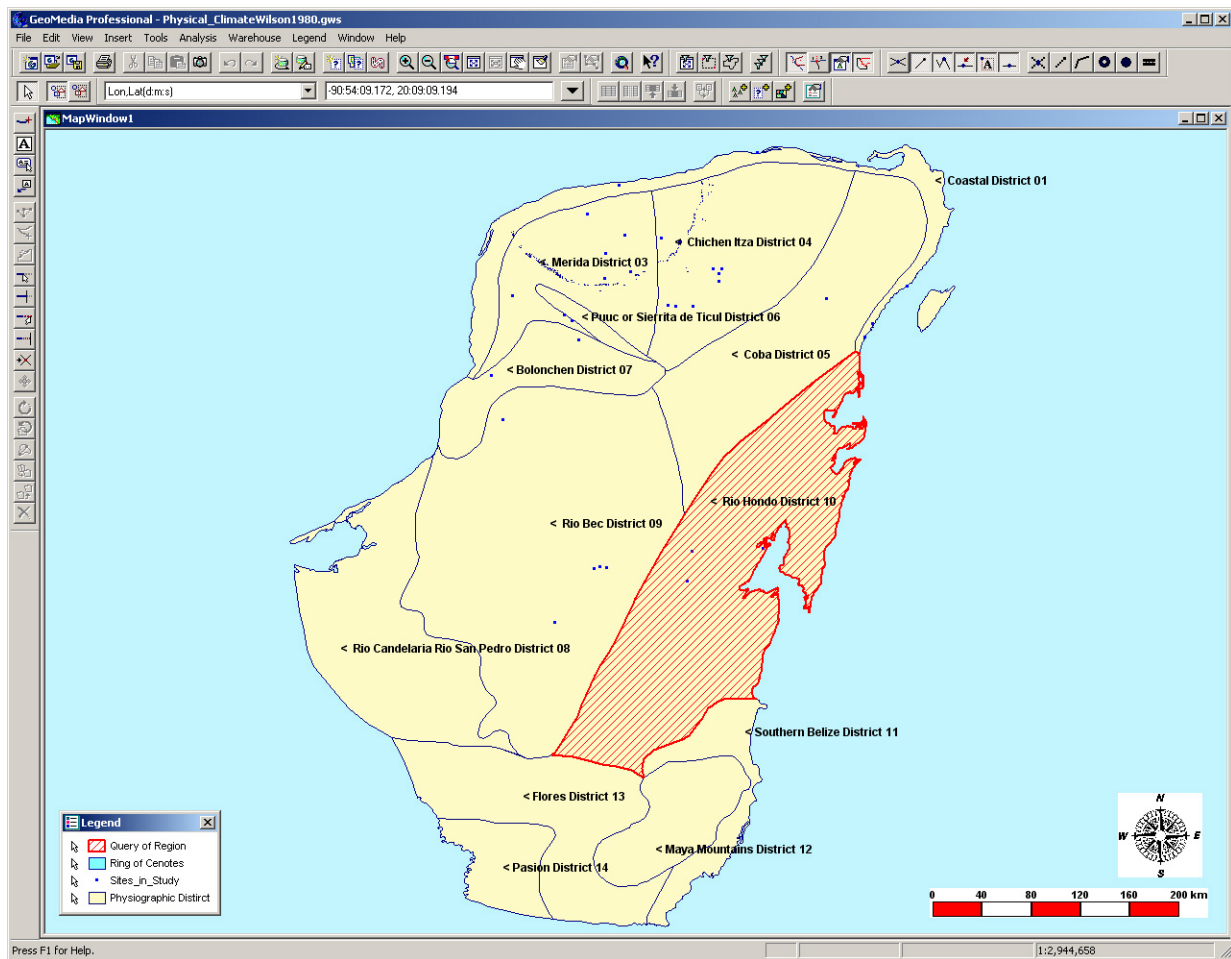


Figure 5.62 Wilson's Rio Hondo District in the project GIS.

completed at the site and current activities consult (Nalda, Evelia Campana and Lopez Camacho 1994a, b).

Dzibanché and its southern neighbor Kohunlich are in Wilson's (1980) Rio Hondo District (Figure 5.62). In general, the district has low relief with northeast to southwest trending fault depressions, streams, lakes, lake beds, and large expanses of grass-covered seasonally inundated savannas between low hills. The climate is a mixture of Köppen Type Aw1

and Aw2 tropical rainy, savanna with a well-defined monsoon (INEGI 2001a). Rainfall in the area averages between 1200 and 1300 millimeters per year (INEGI 2001c). Today, real annual evapotranspiration in the area measures between 1100 and 1300 millimeters annually (INEGI 2001b).

Recorded depth to the phreatic in both Dzibanché and Kohunlich measures between 40 and 50 meters below the surface, exceeding the technological capabilities of the Prehispanic inhabitants. In western portions of the Rio Hondo District aquifer depths approach more than 100 meters (Dirección General de Administración y Control de Sistemas Hidrológicos Dirección de Aguas Subterráneas 1989a). Unlike the northwestern portion of the peninsula, many sites found in the Rio Hondo district are located near natural reservoirs and streams. Dzibanché is no exception. Anthropogenic evidence was observed in a few *aguadas* including geometric shape, stone alignments and channels. Several inundated savannas and *bajos* in the area contain standing water for most of the year. Survey revealed evidence of an adaptive regime relying heavily on naturally occurring sources of surface water, and as in Becan and Edzná, instances where the inhabitants must have invested significant amounts energy to drain standing water from architectural groups. The Lamay Group seems to be an example of an

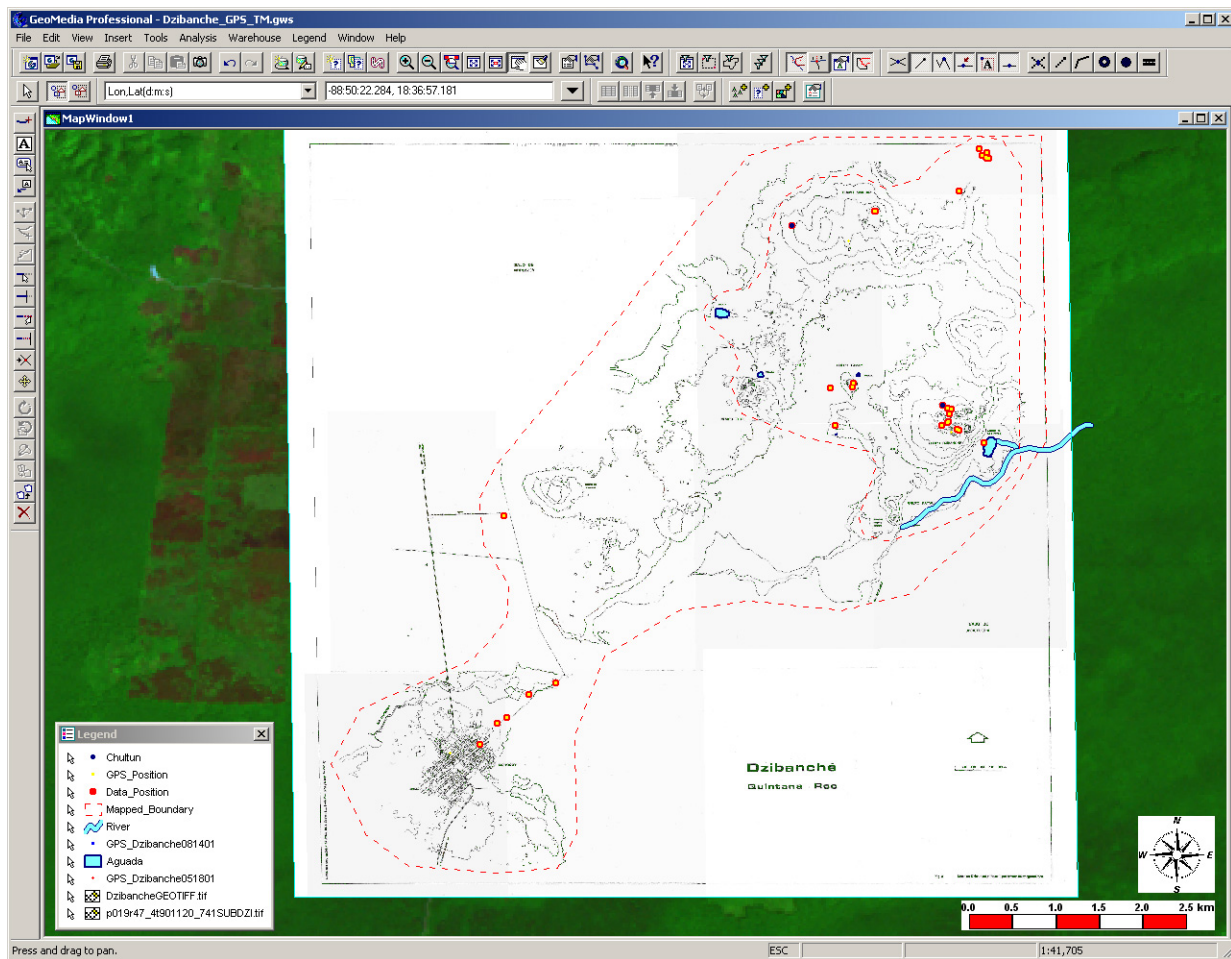


Figure 5.63 Map of Dzibanché in the project GIS, adapted from Nalda et al. (1994). Landsat TM courtesy of NASA.

architectural group constructed on a surface artificially elevated above the surrounding inundated areas.

The settlement of Dzibanché consists of clusters of structures arranged in architectural groups that are separated by expanses of flooded grassy savanna (Figure 5.63). The central portion of the site consists of three groups, Dzibanché, Lamay, and Tutil, spaced approximately 850 meters apart along an east to west axis. The fourth group in the

central portion of Dzibanché, Katali, is positioned 850 meters south southwest of the Dzibanché group, the principal group at the site. Each architectural group in the central area is adjacent to or near one or more *aguadas* of varying size. This *aguada* - architectural group pattern characterizes many of the architectural clusters at the site. Two additional major architectural groups, the Kinichna, and the cluster found in the modern town of Morocoy are at greater distances from the central groups.

The site covers 33.4 square kilometers including several apparently vacant spaces between architectural groups. The site covers a large area including sparsely populated savannas and *bajos*, so total population might not have been as high as other sites where settlement units are more evenly distributed across the landscape. Groups in the southern portion of the site are located on slightly elevated constructed platforms or low hills. The Kinichna to the north is perched on a hill overlooking the four core groups to the south. The collapsed remains of a feature resembling a *chultun* was found in the Dzibanché Group. In the absence of cut stone or plaster, I could not verify that the depression was a water storage chamber.

The Dzibanché group is situated on a hilltop approximately 180 meters northwest of *Aguada de los Patos*, a large *aguada* that appears to be connected to the Rio Escondido by a 250-meter long canal. The canal might be the result of a combination of natural relief and human modifications.

During initial survey, several areas containing the remains of unvaulted architecture were observed in the modern town of Morocoy. By contrast, few examples of non-elite architecture were observed in the compact architectural groups north of Morocoy. The survey area was expanded to include additional peripheral areas. One such area, beyond the borders of the existing map of Dzibanché, is located 1.35 kilometers east northeast of Kinichna. A group is adjacent to an L-shaped *aguada* measuring 120 meters wide by 150 meters long. The *aguada* is naturally formed by the convergence of surrounding hills. The geometrically straight rim of this *aguada* suggests that the inhabitants made modifications to expand capacity and improve accessibility. The *aguada* is filled with silt and soil and overgrown with tall grasses and a few small trees excepting a 30 wide by 40-meter long section on the southwestern corner that contains standing water. I mapped the adjacent architectural group containing eight to ten low platforms dispersed along a hillside to the south that sloped down to the



Figure 5.64 Low platform at domestic group near an *aguada*.

rim of the *aguada*. The remains of the group cover an area measuring approximately 0.013 square kilometers. Several of the irregularly shaped platforms were constructed of rough cut stones and small cobbles (Figure 5.64). Others consisted entirely of cobbles and small stones.

Surface ceramics and lithics collected at the bases and tops of the remains of each platform, as well as activity areas situated near the rim of the silted-in *aguada* support my

inference that the group was domestic space. Ceramics collected in this area belong to the Chicanel and Tihosuco y Chakan Complexes and date the earliest occupation of this group to a period from 300 B.C. to A.D. 250 / 300. The highest frequency ceramics from all other areas surveyed at Dzibanché represent Tzakol or Tepeu 1 and 2 Complex ceramics dating to a period from A.D. 250 / 300 to 900 / 950. The data from the *aguada* group support my notion the earliest settlement units will occur near natural water sources.

A second area located one kilometer to the west of the Kinichna contains the remains of platforms supporting unvaulted domestic structures. The area consists of relatively flat elevated terrain covering approximately 0.05 square kilometers. Although several platforms in the group were surveyed, only one elaborately constructed *chultun* with a finely cut stone neck was found. The *chultun* was located at the base of a single platform. Additional survey of the immediate area failed to reveal additional water management features such as *aguadas* or *bajos*, suggesting the *chultun* was a necessary strategy for settlers in this portion of Dzibanché.

Several other areas north of Morocoy contain poorly preserved remains of low platforms and unvaulted structures. Survey at Dzibanché failed to reveal evidence that large-scale

hydrological management supported or favored an elite segment of society or that differential access to particular water resources existed. However, the patterned location of vaulted groups in elevated portions of the site and evidence of small platforms and common households distributed throughout low lying areas suggest that a segment of society might have enjoyed preferential access to areas that were less prone to seasonal flooding and the discomfort of numerous hazards associated with living adjacent to standing water in subtropical settings.

Today, substantial portions of the area are seasonally inundated. Some low-lying areas contain standing water throughout the year. The clustered settlement pattern discussed, wherein the major architectural groups are grouped near reservoirs suggests that these areas were considered the most favorable locations. The evidence from *Aguada 4* provides further support for early settlement decisions favoring locations with natural water resources. The relative absence of *chultunes* at the site tells us that constructing *chultunes* was not a preferred strategy if other more productive and less labor-intensive options were available.

Kohunlich

Kohunlich, a second order site (Garza and Kurjack 1980), is situated approximately 53.8 kilometers west southwest of Chetumal. The site is distinguished for its monumental architecture and prominent stepped-pyramid, Los Mascarones, having eight massive stucco masks lining a central stairway. Los Mascarones is situated at 16Q 311023mE, 2037488mN UTM, 88° 47' 20.948" West, 18° 25' 08.818" North. The settlement contains evidence of a widely distributed substantial initial occupation during the Middle Preclassic Period, Mamon Ceramic Complex, dating to 600 to 350 / 300 B.C. (Nalda 2002; Nalda and Velazquez 1995). According to Nalda and Velazquez (1995), the earliest habitational areas seem to occur in marginal areas near depressions that might have contained water throughout the entire year. Interestingly, a Late and Terminal Classic Period reoccupation effectively increased population density at the settlement through compartmentalization of existing structures rather than expansion beyond earlier site boundaries. This scenario suggests that some groups on a micro-scale might have experienced a form of circumscription that had an impact on site development. For the most part, the evidence presented in this section argues against resource circumscription as the

principal causal factor in the compartmentalization of structures at Kohunlich.

Between the Preclassic and Late Classic Periods, population declined substantially with a repopulation of the site during the Late and Terminal Classic Periods A.D. 600 – 900 (Nalda 2002; Nalda and Velazquez 1995). The name Kohunlich refers to a geographic characteristic known as the Cohoon Ridge, *corozzal o lomerio de corozos*, and the name of a nearby camp. While completing fieldwork for his doctoral dissertation, Merwin (1912) named the site Clarksville after another camp in the area (Cortes de Brasdefer 1998).

After a 1968 episode of looting at Structure 8, Victor Segovia, an INAH archaeologist who had a penchant for innovative landscape design, was invited by the governor of the State of Quintana Roo to survey and excavate Kohunlich. In subsequent years Segovia excavated and restored several buildings in the central precinct. In 1978, the federal government of Mexico funded additional research at the site including Fernando Cortes de Brasdefer's archaeo-astronomy investigations (Cortes de Brasdefer 1998).

Andrews (1987) made architectural drawings, surveyed, and completed a preliminary map of the central precinct in 1981 that he published in 1987. The current ongoing Project

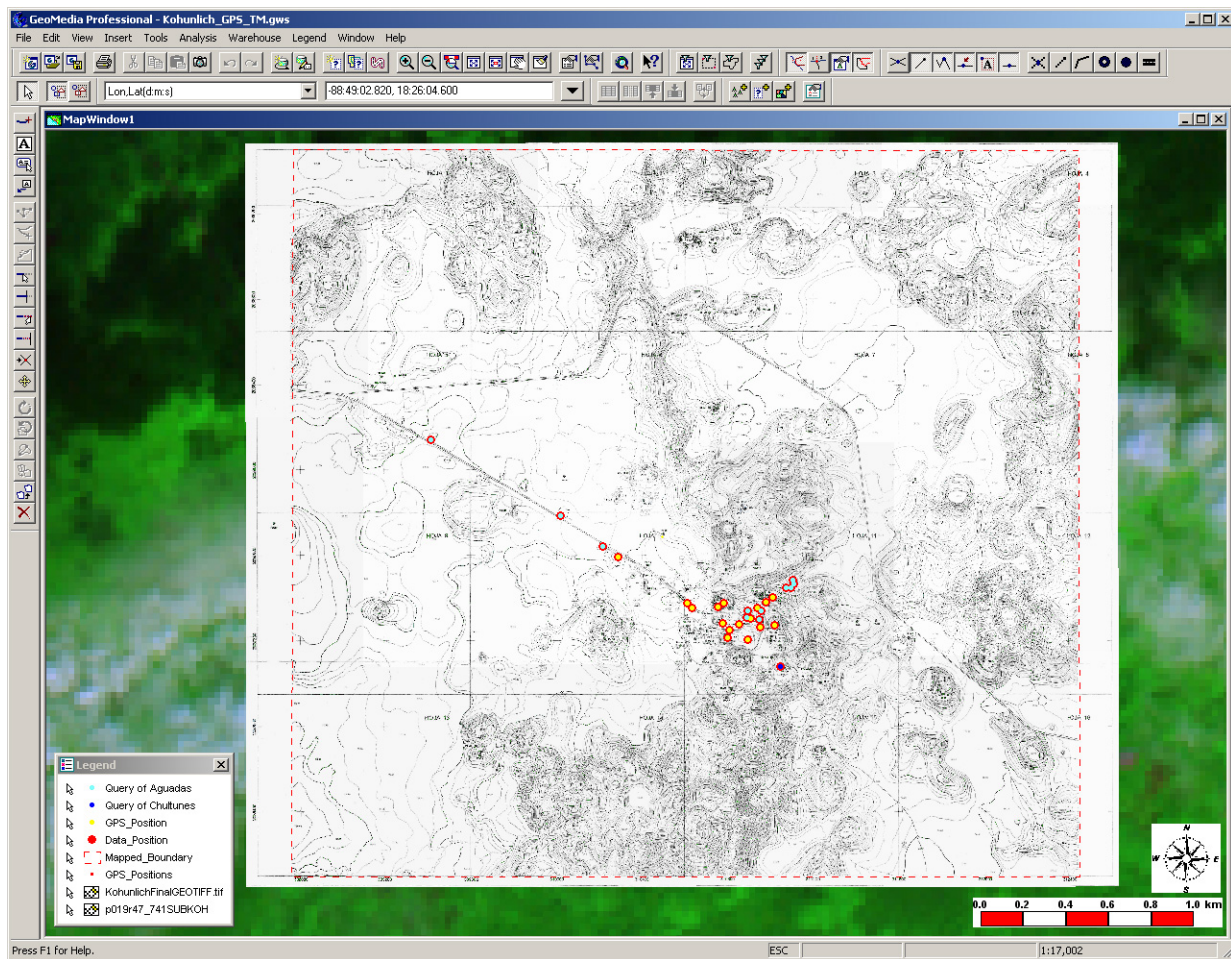


Figure 5.65 Map of Kohunlich in the project GIS, adapted from Nalda et al. (1998, 2002). Landsat TM courtesy of NASA.

Kohunlich began in 1993 under the direction of Adriana Velazquez who is now the Director of Centro Regional INAH Quintana Roo. Nalda (Nalda 1998, , 2002; Nalda et al. 1998) published a topographic map covering approximately 14 square kilometers (Figure 5.65). The ongoing field study by INAH archaeologists included completion of 300 stratigraphic test pits and extensive excavation of several groups resulting in the dating of many major structures at Kohunlich.

Kohunlich lies within the same depth to phreatic zone as Dzibanché (Dirección General de Administración y Control de Sistemas Hidrológicos Dirección de Aguas Subterráneas 1989a). Therefore, wells do not fit the profile. During fieldwork at Kohunlich, five *aguadas* and one *chultun* were surveyed. There are several more *aguadas* located throughout the site. Architectural groups located beyond the central precinct are clustered near *aguadas*. The periphery of Kohunlich consists of low grassy savannas as well as sections of heavy secondary growth forest. Few inundated areas were found in the periphery. Examination of Nalda's (1998) map of the site suggests the Maya avoided low-lying areas. The results of their locational decisions produced a clustered - dispersed settlement distribution in the cultural landscape similar to the Dzibanché pattern. A major portion of the architectural center of mass at Kohunlich is clustered in areas that are elevated between five and 15 meters above the surrounding terrain. A feature known as the *cañada* (a canal) surrounds the northern portion of the central precinct. Today, as in the past the *cañada* channels water around the site core and into an *aguada* 137 meters northeast and 30 meters beneath the architectural center of



Figure 5.66 *Aguada* at Kohunlich.

mass (Figure 5.66). A rectangular one-meter deep depression known as the Plaza Hundida "sunken plaza" has a retaining wall and circular structure along the southern rim and stairways leading from the terrace level on the eastern rim to the plaza floor. Cut stone drains divert water from the northern edge of the Plaza Hundida onto the slope and eventually into the *aguada* 30 meters below. The drains might be recent in origin to insure that the Plaza Hundida does not retain water during the rainy

season. The possibility exists that the plaza functioned as an *aguada*.

A few of the *aguadas* located in the periphery of Kohunlich were surveyed. Each *aguada* investigated was located near the access road to the site. The remains of a small architectural group were adjacent to one *aguada* but no evidence of vaulted architecture noted. It is highly likely that the two *aguadas* nearest to the road were borrow-pits used during construction of the elevated roadway leading to the visitor's center. The data collected at Kohunlich, including evidence for modifications to *aguadas*, construction of *chultunes*, and drainage features, suggest the inhabitants modified their environment to manage or enhance accessibility to water resources. The Maya of Kohunlich preferred locations near existing depressions and bajos where water would have been available throughout the entire year. Although only one *chultun* was observed during fieldwork, local inhabitants and site guards stated that several more existed but were located in remote parts of the site. Kohunlich is situated in an area that would have rarely encountered water stress related problems. In all other areas across the peninsula where naturally occurring sources of water are abundant, the Maya rarely invested substantial amounts of energy constructing storage features.

Contrastingly, more energy was spent enhancing existing reservoirs. Architectural groups of varying scale are clustered near the ubiquitous depressions and bajos dotting the landscape. This pattern of dispersed clusters and uniform distribution of resources does not lend itself to grand-scale management as a single concentrated source might.

Causes, Effects and Possibilities

The evidence from various sites presented above builds a strong case for rejection of both Wittfogel (1957) and Carneiro (1970) as viable explanations for the rise of complex society in the portion of the Maya Lowlands investigated for this paper. Three sites, Becan, Calakmul, and Edzná have evidence of what appears to be large-scale hydrological management systems. Edzná's system of canals and *aguadas* or reservoirs surpasses the other two in complexity. Chronological data are not available to demonstrate concurrent increases in complexity of water features and administrative or elite architecture at any site. Seemingly large-scale hydrological features might be accretive rather than orchestrated by a single individual or segment of society. Moreover, sites such as Dzibilchaltún have clear evidence of stratification and complex society as evidenced by monumental architecture and variations in



Figure 5.67 Left Structure 44 and the Plaza at Dzibilchaltún courtesy of E.B. Kurjack, Right Popol Na at Edzná.

complexity of domestic groups but relied on uncontrolled and apparently unmanaged water wells. Figure 5.67 depicts the architectural similarities between Structure 44 and the Popol Na. Clearly the hydrological regimes were very different at each site. Thus, factors other than water management or the presence of natural water resources contributed to complexity as indicated by the similar cultural landscapes of each settlement. Sites with extensive hydrological features are located in areas where standing water and localized flooding during the rainy season continues to present problems for modern-day inhabitants. Furthermore, evidence presented in this paper demonstrates that the Maya were able to cope in all parts of the peninsula regardless of localized absence of surface water. The construction of *chultunes* and wells most likely

represents small-scale family or kin-based activities. My evidence points out that at both Uxmal and Calakmul, *aguadas* (often cited as evidence of large-scale communal efforts) were walled out of elite and administrative spaces. This condition argues against large-scale hydrological management systems as a source of agromanageial centralized power as in Wittfogel (1957). Like the Dzibilchaltún and Edzná comparison mentioned above, sites like Sayil and Uxmal relied to a large extent on *chultunes* yet contain evidence of a stratified social system. The Puuc and Bolonchen Districts represent areas where options for hydrological adaptive strategies were severely limited, yet the ancient Maya thrived. Their physical environment did not circumscribe the Maya as Carneiro might suggest.

On the coast the Maya were able to find fresh water in naturally occurring *cenotes*, springs and sea estavellas. Therefore, little or no adaptive efforts were needed. Farther inland the physical environment provided varied opportunities and limited to an extent options available to the Maya.

Over the duration of fieldwork, 42 *aguadas* (natural or culturally modified lakes), three *aguaditas* (household *aguadas*), three *akalchens* (early-stage *cenotes*), one *bukte* (storage pit), four canal systems, 20 caves, 68 *cenotes* (sinkholes with water), 88 *chultunes* (storage pits), one dam,

two sea estavellas (marine freshwater springs), nine springs, five *haltunes* (pools of water), 51 wells, five *rejolladas* (dry sinks), five *sartenejas* (seasonal pools of water), numerous lakes, and associated architecture were measured or mapped at 32 sites. See Appendix D for abbreviations for these features.

Table 5.1 illustrates frequencies of all known features by site for 29 of 32 sites surveyed for this study. The table is ordered by Wilson District beginning with the Coastal District sites, Isla Cerritos, Noh Ichmul, Tulum, Xcambo, Xcaret and Xelha. Acanceh, Aké, Dzibilchaltún, and Mayapan are in the Merida District. The Akalchen Group, Chichén Itzá, Cumtun, Dzib Chaac, Izamal, Rejollada Ixbaac and Yula are located in the Chichén Itzá District. One site, Coba, is located in the Coba District. Nohpat and Uxmal are in the Puuc or Serrita de Ticul District. Bolonchen District sites include Acanmul and Sayil. Five sites, Becan, Calakmul, Chicana, Edzná and Xpuhil in the Rio Bec District were surveyed. Lastly, Dzibanché and Kohunlich are located in the Rio Hondo District. Table 5.1 also provides a visual cue to patterns in adaptive options by physiographic district this research revealed. Wittfogel's and Carneiro's ideas do not appear to fit the data from the Yucatán Peninsula. Instead the study revealed that environment across the region

Table 5.1
Presence Absence of Water Features by Site

SITE	AGU	AKA	AKT	BAJ	BUK	CAN	CAV	CEN	CHU	EST	HAL	LAK	PET	REJ	RIV	SAR	SAV	SPR	WEL
Isla Cerritos										2			1						
Noh Ichmul																			1
Tulum				2				1	1									4	
Xcambo													1					6	1
Xcaret								1										1	
Xelha	1							1										1	
Acanceh							1	2								6			2
Aké	1						2	4			1					8			1
Dzibilchaltún								1								5			112
Mayapán		2					3	22								3			
Akalchen Grp		1					1		1					1					1
Chichén Itzá								7	30					4					4
Cumtun								1	2					1					
Dzib Chaac		1					1												
Izamal								1											1
Rejol Ixbaac														1					1
Yulá								1	1										
Cobá	8		1				2	1	2		2	5				4			3
Nohpat									4								1		
Uxmal	12				1				92										
Acanmul									2								1		1
Sayil	4								334										
Becan	3			1		1			12								1		
Calakmul	13					5			26										
Chicana	1		1						2								1		
Edzná	84					31			12										
Xpuhil									1								1		
Kohunlich	5			1		1			2								1		
Dzibanché	8			2		1			2						1		1		

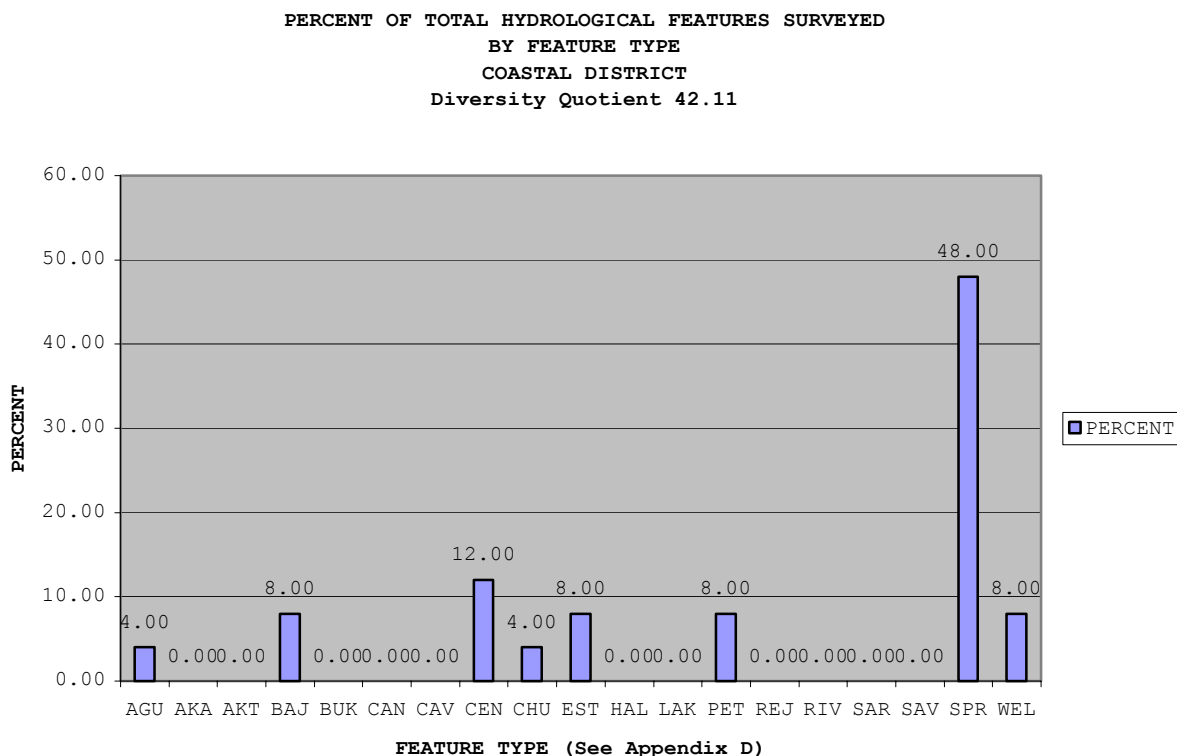


Figure 5.68 Chart showing percent of total hydrological features surveyed by feature type in the Coastal District.

provided opportunities but limited the number of adaptive options available to the ancient Maya given their level of technology. Moreover, A pattern of adaptive strategies and options exists in the region. For example, Coastal District sites (Figure 5.68) relied on springs, *ojos de agua*, sea estavellas and *cenotes*. See Appendix D for a list of the abbreviations for hydrological features used in this table and others. *Cenotes* and springs are functionally similar. Size is the major difference between the two features in the Coastal

District. Where natural sources of water were sufficient to support populations in areas such as the Coastal District, the Maya invested little or no energy to modify these features. Instead, they exploited them rather than building water storage reservoirs or chambers. I calculated a diversity quotient (the number of hydrological feature types documented at every site in each district divided by the total number of hydrological feature types in the region) to compare diversity. A high diversity quotient suggests a wider variety of options were available for the inhabitants in the area. A lower diversity quotient might indicate the district had sufficient natural resources to support populations or few adaptive options were available. The Coastal District had the second highest diversity quotient in the region, 42.11. Figure 5.68 both numerically and graphically demonstrates this diversity. Excluding Mayapan, the dominant adaptive option in the Merida District (Figure 5.69) is wells. Mayapan lies near the southern boundary of the district on the ring of *cenotes* and has, not only the highest count of *cenotes* in the district, but also the highest density of *cenotes* per square kilometer of sites sampled for this paper. Like the coastal sites, the least effort principal applies. No *chultunes* were noted during survey of the Merida District. This is robust evidence in support of

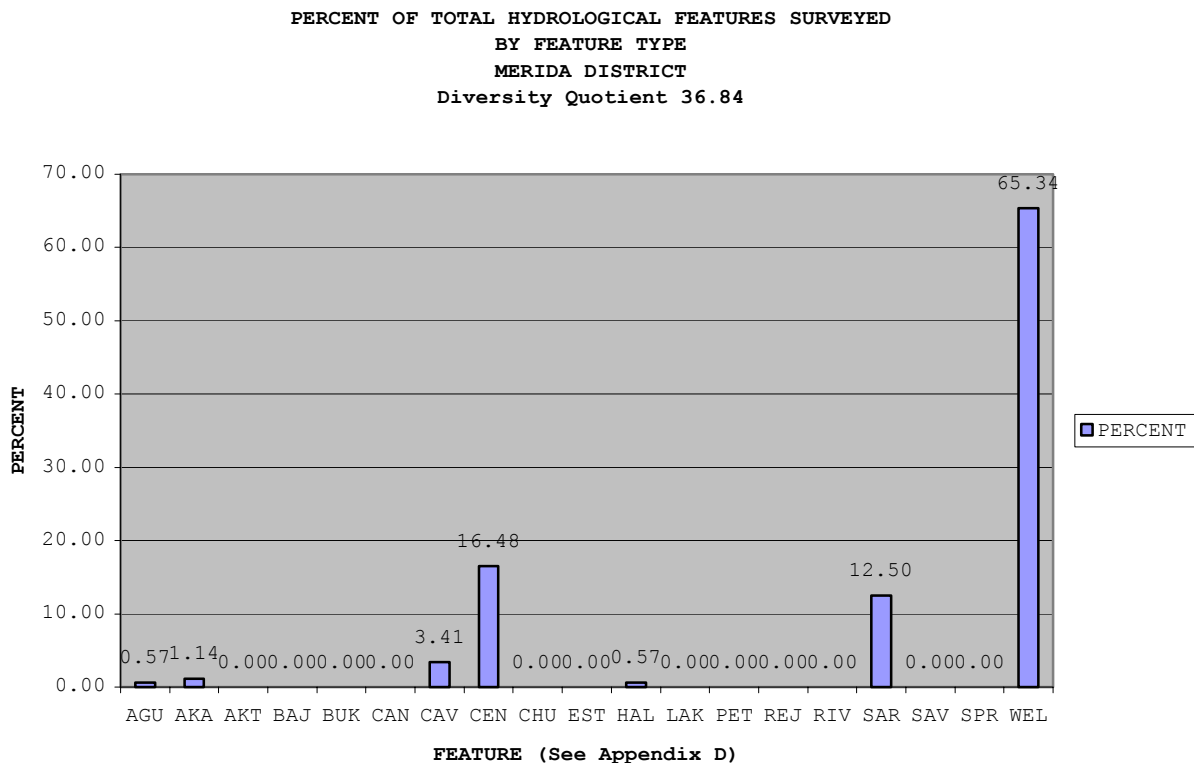


Figure 5.69 Chart showing percent of total hydrological features surveyed by feature type in the Merida District.

the notion that the Maya preferred to excavate wells or employ naturally occurring features rather than invest time and energy constructing features that were dysfunctional during a portion of the year. Clearly, wells were more reliable sources of water. The diversity quotient for the Merida District is 36.84, representing more homogeneity in adaptive strategies.

The Chichén Itzá District (Figure 5.70) marks the transition from wells to chultunes and an increased reliance on

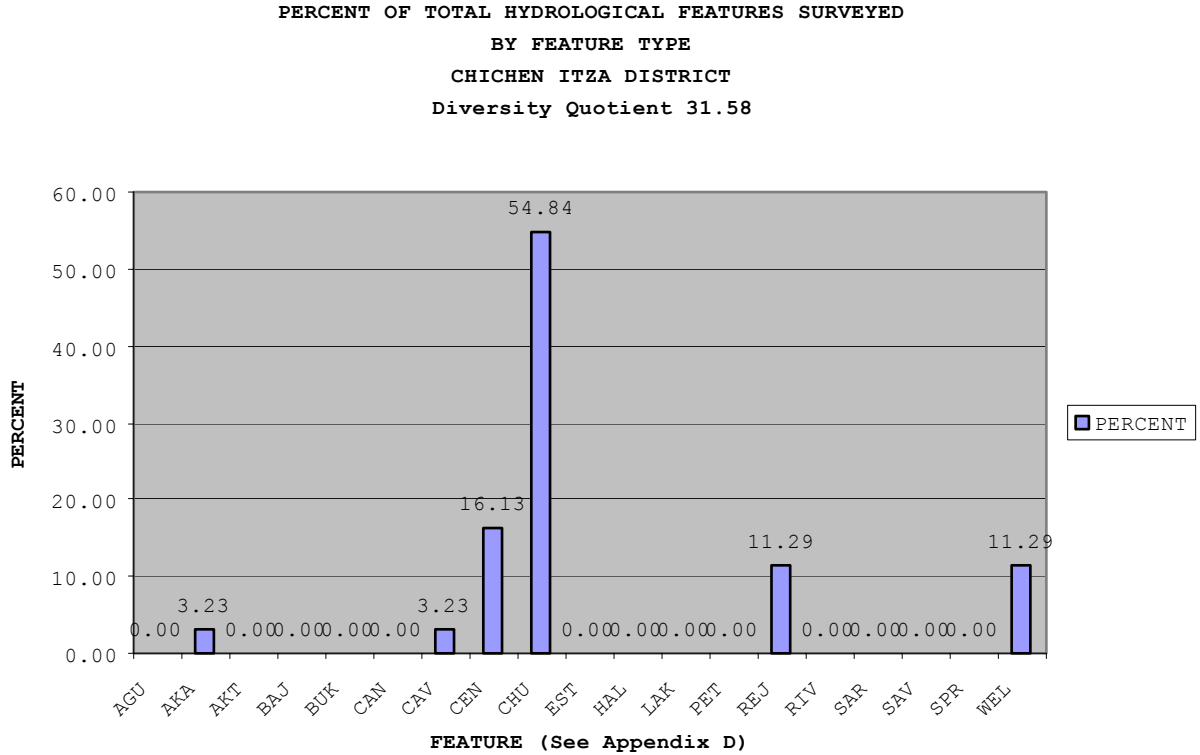


Figure 5.70 Chart showing percent of total hydrological features surveyed by feature type in the Chichén Itzá District.

cenotes as primary sources of water. *Cenotes*, caves, and *aguadas* to an extent, resulted from natural conditions. In areas where natural water was available, fewer active adaptive strategies requiring higher labor investments were noted in the Chichén Itzá District. Those that existed might have been constructed for convenience rather than necessity. The diversity for the district is 31.58 suggesting a more limited environment for development of hydrological management systems.

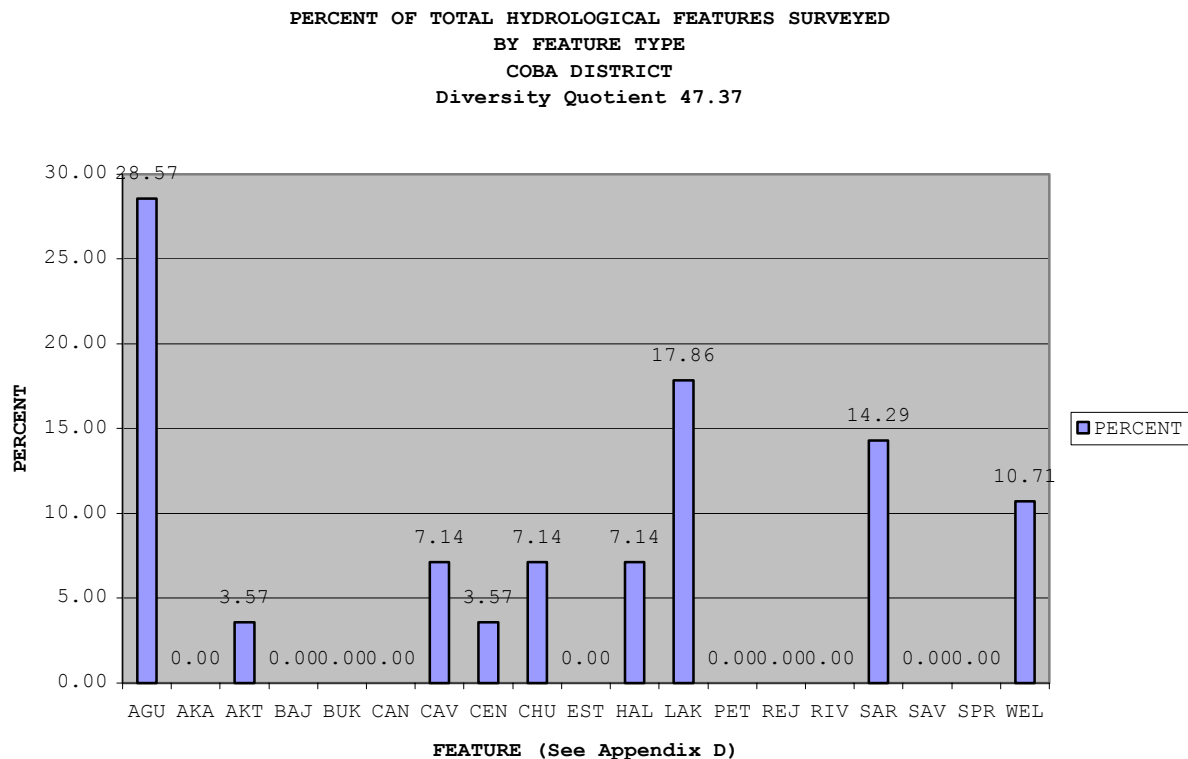


Figure 5.71 Chart showing percent of total hydrological features surveyed by feature type in the Coba District.

This number is reflected in the high proportion of chultunes to other strategies. Coba (Figure 5.71) stands out as having the highest diversity quotient, 47.37, in the sample. Although the inhabitants lived close to several lakes, they exercised the widest variety of strategies. The physical environment favored human settlement in the area. Clearly, the Maya of the Coba District faced few water related problems. A few chultunes were found at Coba. These might have functioned for purposes other than water storage or were strictly for convenience. Adaptive

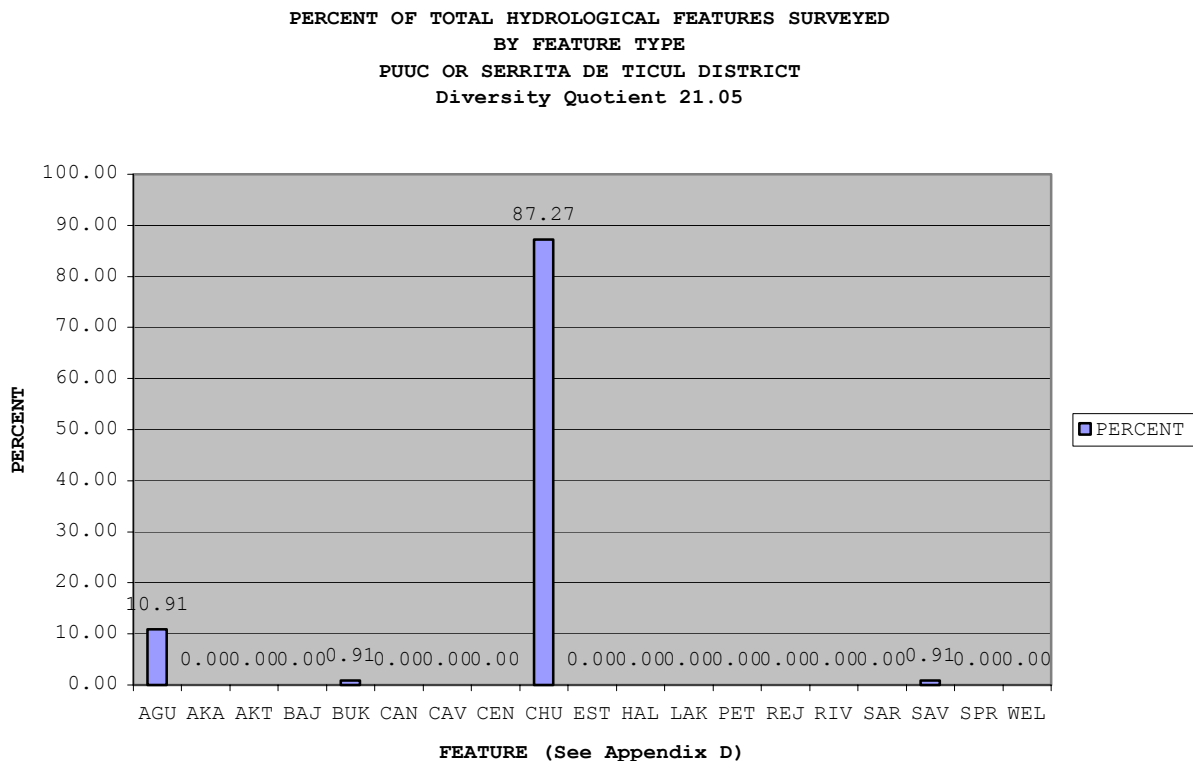


Figure 5.72 Chart showing percent of total hydrological features surveyed by feature type in the Puuc District.

strategies in the Puuc and Bolonchen Districts were dominated by *chultunes* and to a much lesser extent *aguadas*. At the Puuc or Serrita de Ticul District sites, Uxmal and Nohpat (Figure 5.72) herein referred to as Puuc District sites, two feature types, *aguadas* and *chultunes*, account for 98.18 percent of hydrological features recorded during fieldwork. A low diversity quotient, 21.05, suggests that the Puuc like the Bolonchen District provided an extremely narrow range of options for water. A total of 432 (82.1 percent) of the 526

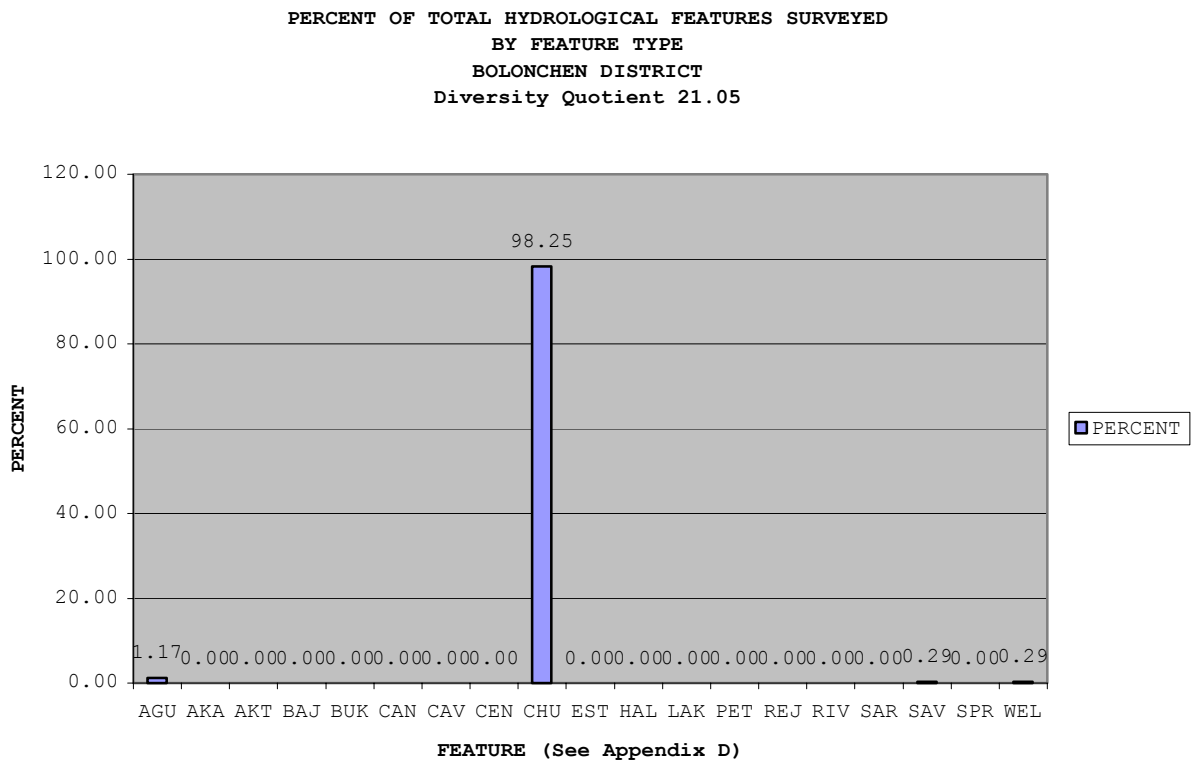


Figure 5.73 Chart showing percent of total hydrological features surveyed by feature type in the Bolonchen District.

chultunes considered for this study existed in Puuc and Bolonchen District sites. In addition to the *chultunes*, I noted 16 *aguadas*, one *bukte*, two seasonally inundated savannas and one well. The Bolonchen District sites (Figure 5.73) Acanmul and Sayil represent the most extreme case of limited opportunities revealed in this study. Chultunes represent 98.25 percent of hydrological features recorded in the District. The diversity quotient for this district is 21.05, the same as in the Puuc. Clearly, *chultunes* were vital in the area. Both the

Puuc and Bolonchen have deep aquifers. Thus excavation of wells was not a viable option. Caves were exploited by the ancient Maya as well and are found in the area. None were surveyed as part of this project. Caves did not represent a significant source of water nor were they the principal adaptive option in the district. Certain portions of these two districts, like the Rio Bec and Rio Hondo, see below, could be merged into a single area. However, divisions within these districts have physical profiles resembling coastal or northwestern sections of the Merida district. The similarities between the adaptive strategies found in the Puuc and Bolonchen Districts as well as the wide range of variation in other sections of the zone indicate that although Wilson's Districts might be used for generalized predictive modeling, more work is needed to describe specific regional variants before we can precisely predict hydrological management regimes. I leave this task for the future.

As mentioned earlier, the Rio Bec and Rio Hondo Districts had similar adaptive options. I noted evidence of reliance in both districts on natural resources such as *aguadas*, *bajos*, and savannas, and in one instance a river at Dzibanché. The Rio Bec sites (Figure 5.74) have a higher reliance on chultunes and canals and are almost identical in percentage of *aguadas* to the

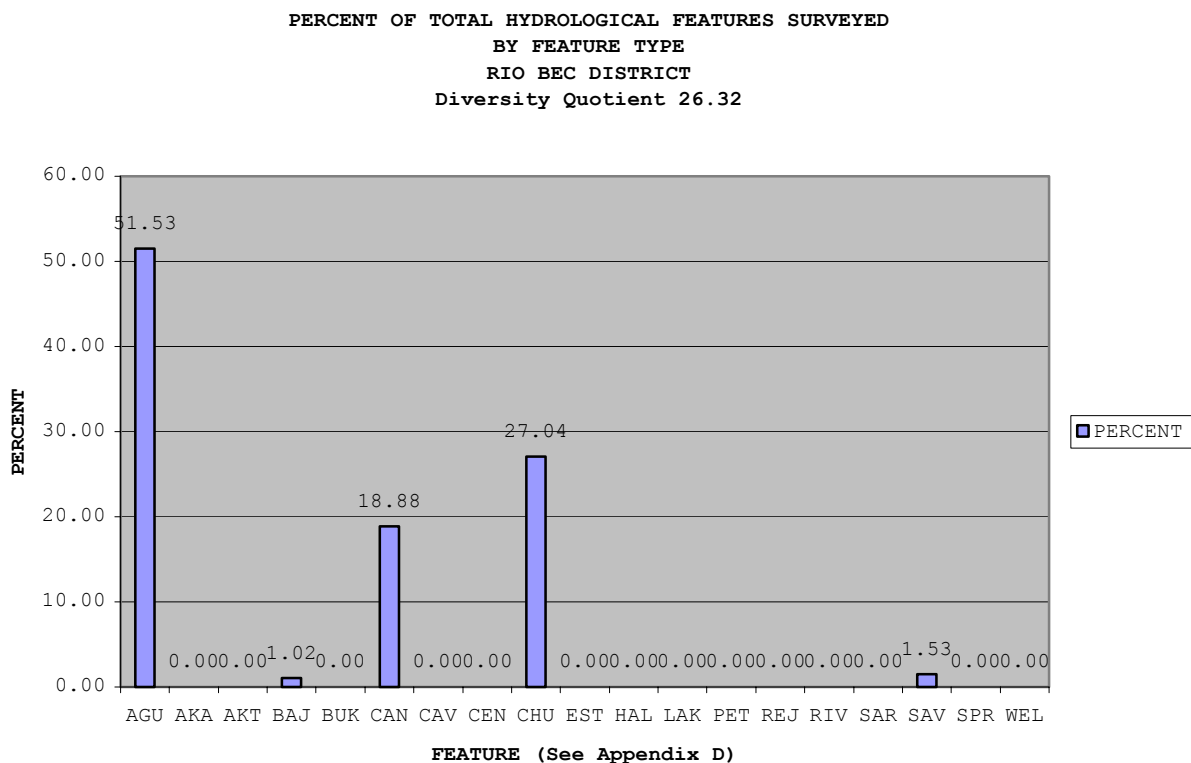


Figure 5.74 Chart showing percent of total hydrological features surveyed by feature type in the Rio Bec District.

Rio Hondo sites. Both districts contain evidence of canal systems. The higher percentage of canals in the Rio Bec District is a result of the canal system at Calakmul and the ubiquitous canals of Edzná. As mentioned earlier, canals are associated with low, seasonally inundated environments, and most likely functioned in part for drainage. Although low, the 26.32 diversity quotient for Rio Bec sites should not be interpreted as indicating the inhabitants of Becan, Calakmul, Chicana, Edzná and Xpuhil experienced water stress related

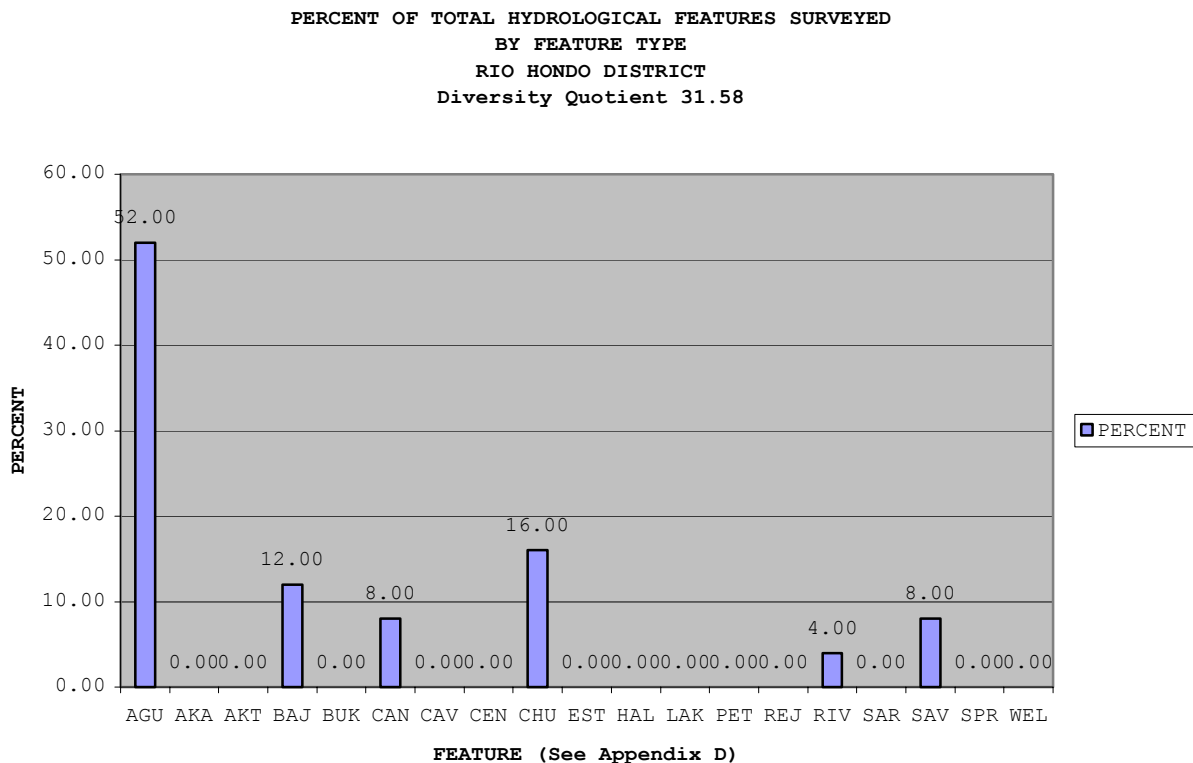


Figure 5.75 Chart showing percent of total hydrological features surveyed by feature type in the Rio Hondo District.

problems. Instead, sections of these sites most likely coped with seasonal flooding. Two Rio Hondo District sites (Figure 5.75) Dzibanche and Kohunlich were surveyed during fieldwork. A 31.58 diversity quotient for the district suggests that inhabitants at these sites faced few if any water related issues as well. Like the Rio Bec sites, *aguadas* represented a substantial percentage of hydrological features surveyed.

As the discussion in this final section demonstrates, variability in the physical environment of the Yucatán

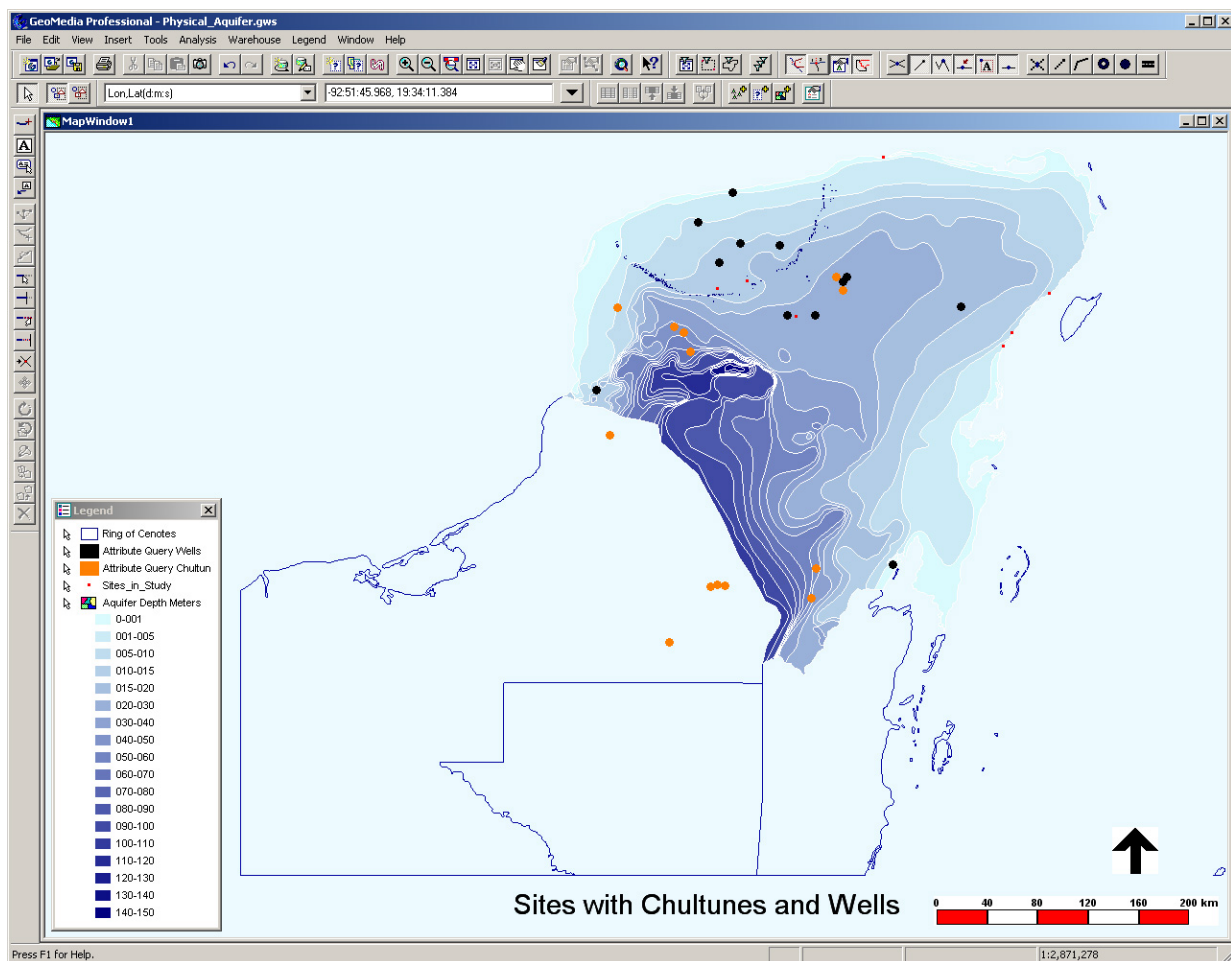


Figure 5.76 GIS screenshot of sites with *chultunes* and wells throughout the region of study, ring of *cenotes* and aquifer depth thematic. Orange dots are *chultunes*, black are wells.

Peninsula provided sets of possibilities. Figure 5.76 illustrates the spatial distribution of two adaptive options, *chultunes* and wells plotted over aquifer depths and the ring of cenotes that follow rim of Chicxulub. The Maya were adept at coping with their environment but limited by their technology. Figure 5.38 shows there were no wells within the trough of Chicxulub. Instead the Maya excavated wells in this area where

aquifer depths were close enough to the surface to reach water with their tool technology. Clearly the evidence points out that variability in hydrological management was closely linked to environmental conditions. Using their technology including an ability to construct water storage features, the ancient Maya were able to populate areas having no apparent sources of water management. Thus water was not a commodity controlled by an elite segment of society as in Wittfogel (1957) or Carneiro (1957). The following chapter provides final thoughts and considerations about the results of this research and implications for further research in light of data collected during 2001.

CHAPTER 6

FINAL THOUGHTS ON WATER AND THE MAYA

Evidence of large pre-industrial urban centers is found throughout the Yucatán Peninsula. A dispersed population living in towns, villages, small clusters of households, and isolated farmsteads supported these cities. Bullard (1960) was the first to describe this pattern as "clustered - dispersed" settlements. Explanations for the evolution of centralization in the region derive from political, economic, and ecological models. Large areas on the Yucatán Peninsula lack surface water. Nevertheless, the Maya settled in these places. This study explores the relationship between water resources and settlement location and attempts to characterize adaptive strategies the Maya employed to extract, redirect, or store water for human consumption. I sought, beyond description, to increase understanding of the role control of water resources and the development of hydrological management systems played in centralization of power and the rise of complex civilization in the Central and Northern Maya Lowlands.

Karl Wittfogel and Robert Carneiro offered two different explanations for the rise of complex society. Wittfogel (1957) argued that the unique ecological and cultural features of Maya society overlay constructional, organizational, and acquisitive

conditions similar to those found in other marginal agro-managerial societies. Although Wittfogel's hypothesis is most often associated with dry-area irrigation societies, his ideas can be examined in a variety of ecological settings. Wittfogel cited the karstic nature of much of the Yucatán plain and hill zone as a limiting factor for hydraulic enterprise and an obstacle to permanent populous settlements. Thus, populations entering the region were first challenged to construct reservoirs to store water for human consumption or locate naturally occurring water. Wittfogel expected to find that hydraulic features throughout much of the Maya Lowlands were playing only negligible roles similar to those found in other agrarian societies. The ancient inhabitants of Yucatán found drinking water in artificial wells, *cenotes*, cisterns or *chultunes*, and man-made or culturally modified natural reservoirs *aguadas*. Wittfogel pointed out that "...even after the introduction of iron implements, the maintenance and use of the man-made wells often required communal action," in some instances the participation of the entire population of a community. He believed the *chultunes* and *aguadas* of Yucatán were fundamental to human survival on the peninsula. He characterized Maya civilization as relatively high in "hydraulic density" and a loose hydraulic society, meaning

hydraulic agriculture lacked economic superiority but was sufficient enough to assure leaders absolute organizational and political hegemony. According to Wittfogel the Maya were an oriental society with regard to social control (Wittfogel 1957:166, 188).

To find support for Wittfogel's ideas, I searched for confirmation in the archaeological record and published documents of centralized coordination of water resources, as evidenced by a substantial increase in complexity and/or size of water management systems taking place before or at the same time as the expansion of central precincts or periods of monumental building activity. Bearing in mind the dearth of comprehensive chronological data to aid in determination of construction sequence at specific sites, I considered evidence for spatial dominance as one way to test the fit of Wittfogel's thinking for the Maya Lowlands. For this study I considered evidence for spatial dominance by a privileged segment of society of areas with natural water features, to be indicated by a presence of vaulted administrative and elite structures, walls, moats or canals to the exclusion of unvaulted domestic structures, as representing greater political integration (Mitchell 1973) and economic sanctions wherein certain individuals or groups might have been denied access to

particular water sources (Childe 1954). A restated version of hydraulics facilitated capturing the nature and extent of water systems management as representing solely organizational behavior rather than the construction and management of large-scale irrigation systems in explanations for the appearance of Maya civilization.

For Carneiro (1970), a critic of Wittfogel, the origins of early states could be best explained as resource circumscription leading to intensification of warfare for conquest. In Carneiro's model, conquered groups became tribute paying political entities under the dominant conquering social group. If this model explains in part centralization and growth of urban centers in the flat plains of the Yucatán Peninsula, we should expect to find evidence of warfare and conquest at a number of higher-order settlements situated somewhat equidistantly from each other and surrounded by a more-or-less equal distribution of lower-order settlements. For this analysis, evidence of warfare included fortifications such as walls or moats and murals, altars, or stelae depicting the material culture of war and conquest. Considering zonal variation across the study area, I expected a degree of variation in size, the architecture of settlement unit integration, or spatial relationships between different zones.

For example, the density of higher-order sites might be higher and distances between them smaller in the southeastern portion of the study area where water resources are more readily available than in the drier northwestern portion of the peninsula where sustainability areas might be either larger or smaller than other environments. If these conditions are found not to exist in the Maya Lowlands, then Carneiro's explanation fails to elucidate the forces impacting the distribution of settlements among the ancient Maya. Interestingly, at several sites including Calakmul and Uxmal, resources considered to be vital to survival in the area were effectively walled out, suggesting that walls might have functioned in other ways as well; for example to define functional space as it related to socioeconomic status or distinguish domestic spaces from places where commercial and political tasks were accomplished.

I addressed a series of basic questions to ascertain whether or not Wittfogel or Carneiro explain the development of high civilization among the Maya, determine the role water systems played in the lives of early settlers on the peninsula, and describe adaptive strategies employed to settle the region. (1) Were early settlements in Yucatán located adjacent to water sources? (2) What other additional factors might have affected settlement in the region? (3) What types of natural and

artificially modified water features were employed as adaptive strategies to manage water supply and water storage systems?

(4) What features enabled the Maya to expand into marginal areas? (5) What regional variants of adaptive systems occur in the northern peninsula? (6) Can centers of innovation and mechanisms of propagation for regional variants be described as well as their influence upon regional and local settlement patterns? (7) Are varied adaptive systems related to physiographic factors, such as localized climatic variation, elevation, subsurface or surface geological characteristics, or vegetation coverage? (8) Can we construct a settlement chronology based on water management systems? (9) Do micro-level settlement patterns reveal rules governing transport of water? (10) Were the ancient Maya circumscribed by a water resource base? (11) What if any contribution did water systems management have upon the rise of complex society in the northern Maya lowlands? (12) Can we refer to the Maya as a hydraulic society?

Prior to field survey I reviewed existing data on the topic of water resources and Maya settlement. Fieldwork consisted of five operations. During Operation 1, I collected archaeological data including site maps, the location and frequency of natural water sources, water storage or diversion,

and settlement locations by type and rank-order from regional offices of the National Institute of Anthropology and History, INAH, in the states of Campeche, Quintana Roo, and Yucatán. During Operation 2, I visited the twelve upper-order sites according the *Atlas Arqueologico del Estado de Yucatan* (Garza and Kurjack 1980) in the study area, to collect GPS positions, verify existing geographical coordinates, identify and classify water features, and complete selective surface collections. During Operation 3, I conducted an intensive field survey of nine upper level sites, one from each of nine physiographic districts defined by (Wilson 1980). Field survey involved reconnaissance and mapping the locations of natural and culturally modified or constructed water sources and architecture and registration of artifact frequencies by functional location within the site. During Operation 4, I surveyed and mapped one lower order site (Garza and Kurjack 1980) from each of the nine physiographic districts (Wilson 1980) in the study area to document principal settlement units, the extent of site development, and review the form and complexity of hydraulic management systems. The object of Operation 4 was to find out whether or not settlement rankings, based on population density and architectural development, both

measures of complexity, correlate positively to site-specific variation in the complexity of observed adaptive strategies.

I suspected a correlation existed between natural water features and the location of ancient Maya settlements. Moreover, awareness of the apparent association is useful for discovery. The study provided an opportunity to test the utility of GIS and remote sensing in archaeological reconnaissance. Operation 5 was designed to demonstrate that this fundamental relationship existed. Prior to fieldwork, I visually interpreted Landsat Thematic Mapper imagery provided to the project through a grant from NASA's Scientific Data Purchase Program, orthorectified air photos, and a variety of 1:250,000 scale physical maps of the peninsula procured from INEGI, Instituto Nacional de Estadística Geografía e Informática, in the GIS environment. Using tested criteria and methods developed by Winemiller (1998, 2000a, b) employing a suite of environmental factors such as the presence of natural water sources, deep soils, evapotranspiration rates, proximity to the phreatic, and favorable relief, I visually classified remotely sensed images then overlaid the image data with physical information from thematic maps and identified areas having the highest potential for human habitation. After the process was completed, a sample area was selected, geographic

coordinates recorded and the area reconnoitered to establish whether or not the predicted settlement existed.

Descriptive statistics and contingency tables were employed to identify correlations between particular adaptive strategies and settlement unit type. I used quadrat analysis for larger sites where sufficient data were available. Calculated frequencies by type of hydrological feature were informative for identifying the relationship between environment and location potential for human settlement.

I wanted to know whether or not quantitative or qualitative differences existed between the patterns of material cultural found in hydrological contexts and other domestic activity areas. During fieldwork, I collected artifacts and ecofacts by surface collection or excavation. Ceramics, lithics, and ecofacts were analyzed and catalogued by Virginia Ochoa Winemiller and me. During fieldwork, a total of 3346 ceramic sherds were collected. A total of 1,763 pieces, 52.69 percent, of the entire collection were recovered from water-feature contexts. The remaining 1,583 sherds were found on, or adjacent to non-water features such as the mounded-remains of platforms or structures and residential areas. Using the Type-Variety system implemented by Smith, Willey and Gifford (1960), sherds were classified at the level of type,

group, and complex. The analysis revealed 63 ceramic groups including 140 ceramic types together with unspecified groups and unidentified sherds. After classification, artifact data were entered into a relational database for spatial analysis in the project GIS.

Beginning in January 2001, I spent nine and one-half months completing an intensive survey of 32 archaeological sites on the Yucatán Peninsula. The area of study included the portion of Yucatán within the political boundaries of the modern day states of Campeche, Quintana Roo, and Yucatán, Mexico. The region covers approximately 112356 square kilometers and lies between 18° 6' and 21° 40' North and 86° 42' and 91° 30' West.

Using a Geographic Information System, Global Positioning Systems data collector, and methods developed to convert existing paper maps and published data into digital format, I was able to incorporate an additional 638 features that would have been unavailable to sample. Three previously unknown archaeological sites, *Akalchen*, 3.5 kilometers northeast of Chichén Itzá; *Dzib Chaac*, 19.5 kilometers southeast of Sotuta, and *Ixbaac*, 16.7 kilometers south of Sotuta were discovered as a result of this research. Two sites, *Dzib Chaac* and *Ixbaac*,

were discovered using methods described above for employing GIS and remotely sensed data in archaeological reconnaissance.

I argued that hydrological features encountered in the field represent two modes of adaptive response, either *passive* or *active*. Characterization by mode was useful to evaluate the overall weight and significance of hydrological management within cultural systems. Where sufficient natural water resources existed, the Maya were able to establish settlements without committing considerable amounts of energy and time applying technology to the problems of water procurement. Passive responses required only a settlement decision and occasional but slight modifications to water features, such as excavating an access stairway along the slope of a funnel-shaped *cenote* or *aguada*. These data suggest these modifications appear to be more for convenience than functional necessity. The inhabitants of Mayapan took advantage of the ubiquitous *cenotes* in the area. In some instances the Mayapan residents enlarged openings or cut stairways for convenience. In the littoral, the residents of Xcambo settled around seven springs to supply their need for potable water.

In other instances, natural water features were either insufficient to support populations, seasonally unavailable, or nonexistent. For a variety of reasons, an active response was

necessary to insure a consistent water supply for consumption. Active responses required application of varying amounts of energy and technology to modify existing resources or enhance their ability to store or collect water, or to specifically capture and store water. The inhabitants of Uxmal adapted to seasonal fluctuations in water supply by excavating *buktes* (stone-lined, bell-shaped pits) in the base of *aguadas* allowing water in the soil beneath the base of the *aguada* to infiltrate the *bukte* after the *aguada* was empty. Through the application of hydrological engineering and technology, functionality of *aguadas* extended beyond normal seasonal limitations. The Maya also lined *aguadas* with clay to reduce seepage and constructed stone rims to prevent silt accumulation and provide easy access. In light of my findings there are questions to be answered about the function of *aguadas* at sites such as Uxmal where chultunes were ubiquitous and appear to have been the adaptive strategy of choice. The architecture is seemingly intentionally situated away from *aguadas* rather than adjacent to them. Clearly, more focused research is needed.

At Calakmul and Edzná the residents took advantage of and modified existing topography and natural drainage patterns to divert water away from architectural groups, transport water from one *aguada* to another, and provide overflow storage. At

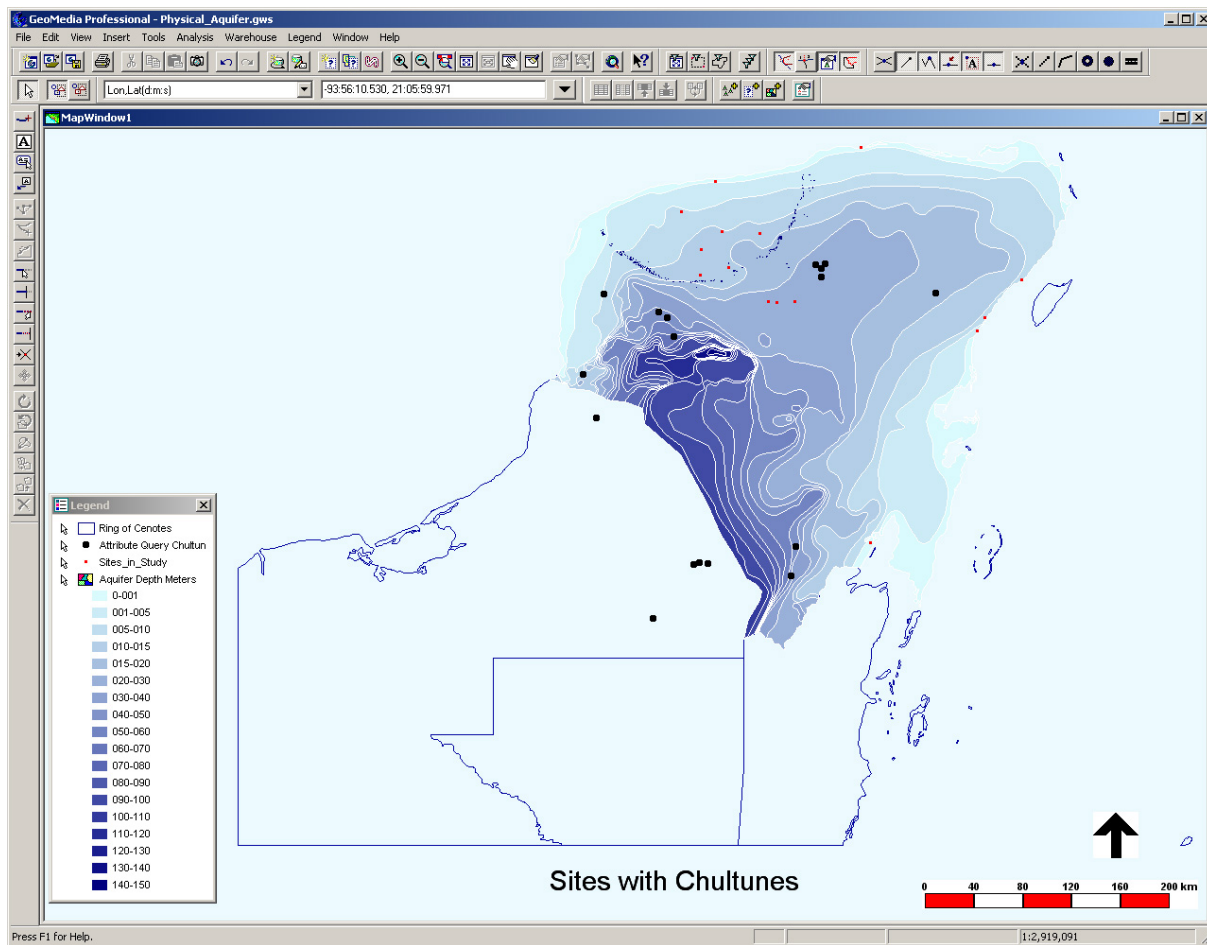


Figure 6.1 Sites with *chultunes* in sample and aquifer depths.

some stage of development, the consolidation and maintenance of canal systems represented coordinated, large-scale undertakings.

Figure 6.1 shows sites investigated that have *chultunes* and aquifer depth in meters below the surface. In most cases, *chultunes* appear not to have been attractive adaptive strategies where aquifer depths averaged less than 15 meters. The two instances where chultunes occurred at shallower depths

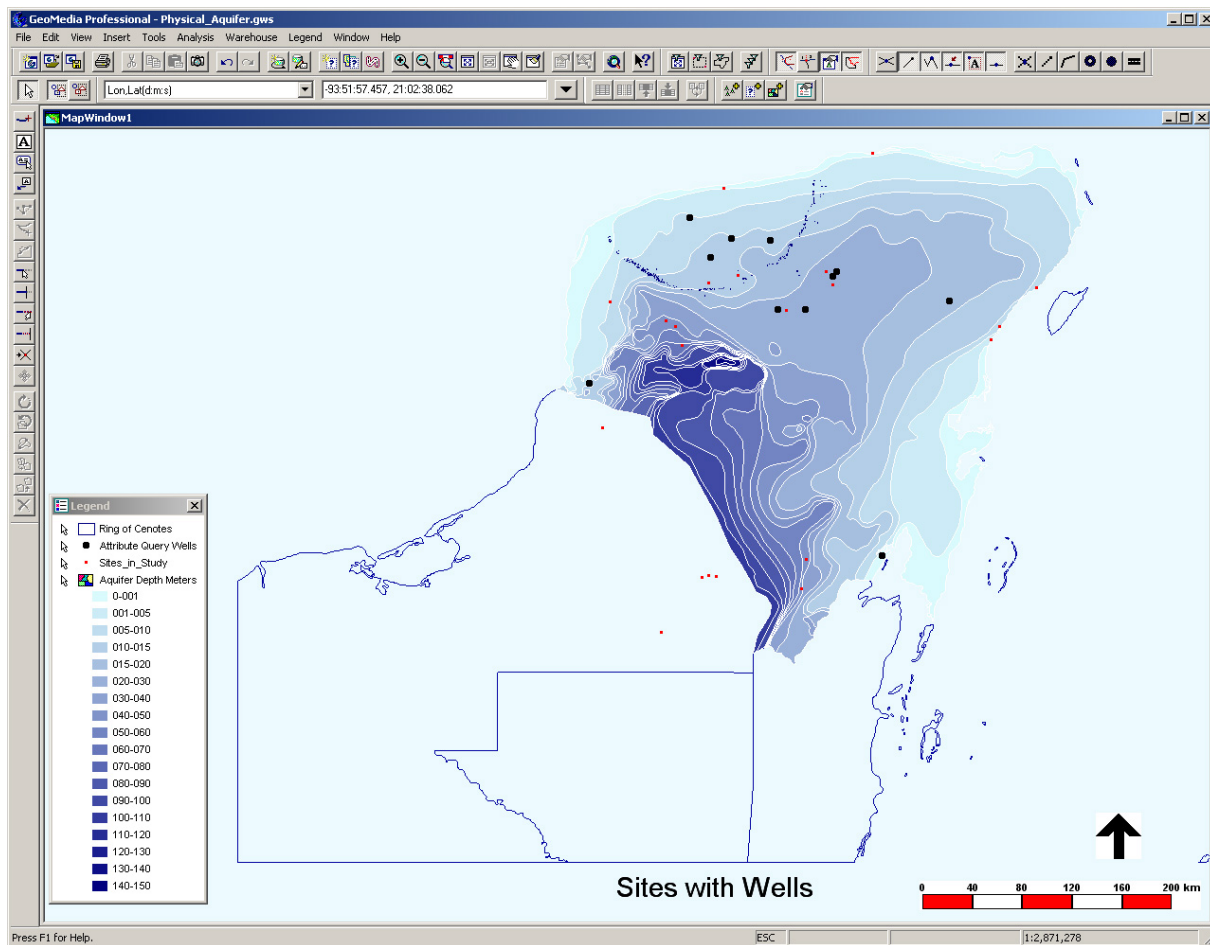


Figure 6.2 Sites with wells in the study and aquifer depth.

might be the result of as yet unidentified localized conditions. No chultunes were found north of the trough of Chicxulub. As the GIS illustrates, the impact had an effect on aquifer depths and in turn adaptive strategies in the zone. The screenshot of observed wells reveals that the alternative strategy to *chultunes* was to excavate wells (Figure 6.2). Clearly, wells would have been more reliable throughout the year. The map does not reveal comparative frequencies. A total

of 112 of 129, 86.8 percent of all wells included in this sample are from Dzibilchaltún. If the three additional sites inside the ring of cenotes, Acanceh, Aké, and Izamal are included, the total figure includes 117 of 129 or 90.7 percent of all wells observed during fieldwork. Fernando Robles and Anthony P. Andrews are conducting intensive survey and excavation of sites near the northwestern coast of Yucatán. Robles (2001 personal communication) mentioned they documented a large quantity of wells in the area. Figure 6.3 shows well occurrence and annual rainfall, another seemingly influential factor. *Chultunes* are the most widely distributed active adaptive strategies in the region.

Chultunes were found in varied densities and contexts at many of the sites sampled. Geographers and archaeologists continue to debate the function of *chultunes*. Data collected for this study and prior research by Winemiller (1997) for Chichén Itzá, also McAnany (1990) for Sayil suggest that some *chultunes* were not watertight. Furthermore, the distribution of settlement units in areas where the construction of functional water storage features represented the only adaptive option available to assure habitability appears to be influenced by the presence and thickness of caprock, the underlying sascab layer, and proximity of bedrock to the surface. Unplastered

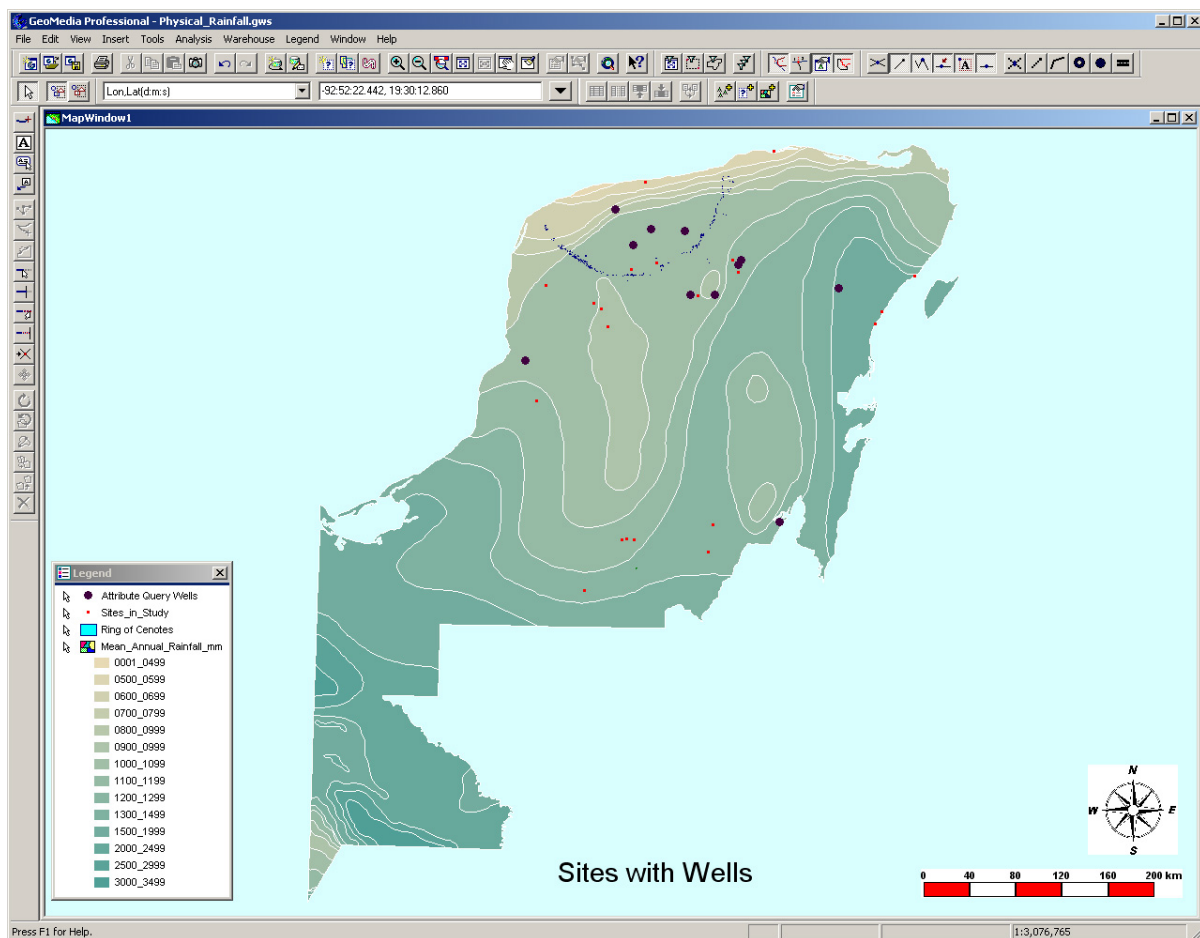


Figure 6.3 Sites with wells and annual rainfall.

pits excavated no deeper than the *sascab* layer are the cumulative remains of mining operations to extract limestone marl used by the ancient Maya for mortar, or they functioned in some other storage-related capacity (McAnany 1990; Puleston 1971; Puleston and Puleston 1971; Sabloff and Tourtellot 1991a). Clearly, an accurate classification of *chultun* function on a site-by-site basis is essential if archaeologists are to accurately represent the range of considerations involved in

ancient Maya locational decisions. The results of this study elucidate three essential factors for consideration in the assignment of site-specific function of *chultunes*, context, surface and subsurface geology, and morphology.

During field survey, I noted settlements that relied on a variety of naturally occurring water resources. Environmental factors, such as climate, subsurface geology, age of geological formations, extent of solution processes, variation in relief, and depth to aquifer shaped a variety of definable environmental zones in the Yucatán Peninsula that provided predictable options for coping with water related problems. These place-specific ecologies provided unique possibilities and limited to an extent the options available to humans for coping with ecosystem variability. This research indicates that the most significant factors beyond the presence of sufficient surface water in determining available adaptive options and choices made by humans were annual rainfall and depth to aquifer. For example, the inhabitants of Acanceh excavated wells or used caves and *cenotes* as sources of water. The ancient inhabitants of Dzibanché and Uxmal relied on *aguadas* and *chultunes*. Mayapan relied solely on *cenotes*, although in some instances the inhabitants converted them into functional wells. At other settlements, Dzibilchaltún for example, most of

the inhabitants relied on a *cenote* or one of over 100 natural or culturally constructed wells found at the site. On the littoral, Xcambo had only springs and no constructed water storage features. In peripheral sections of Aké, only *sartenejas* were found. These pools of water were seasonally unreliable resources, so during the dry season, the ancient inhabitants must have been compelled to transport water from caves or one of several *cenotes* or wells, situated distances in excess of one kilometer from domestic spaces.

To address the question of Wittfogel's hydraulic hypothesis and Maya civilization, I considered evidence from several sites in the region. Becan, Calakmul, and Edzná have evidence of extensive hydrological works considered to be comparable to monumental architecture. Although the moat at Becan is a feature considered by some to be defensive (Thomas Jr. 1981; Webster 1976a), all three aforementioned systems are essentially canals that function to transport and store water for a variety of purposes including draining lowland areas. Constructed canals and modified watersheds of Calakmul and Edzná appear to be accretive features resulting from the collective efforts of various groups at various points in time (Scarborough 1993b) rather than large-scale projects orchestrated by elites to establish a powerbase in hydrological

infrastructure. As such, these features would have ultimately been incorporated into a maintained system through coordinated efforts of a particular group. If the hydrological systems at Becan, Calakmul, and Edzná are considered evidence of a causal relationship between hydraulic management and the rise of complex society, similar logic dictates that a stronger case could be made for interpreting the volume of monumental architecture at a site as the basis for and a measure of centralization and complexity. Clearly, monumental architecture is more widespread at both large and small sites than canal systems. Yet, an argument for causality of monumental architecture has not been advanced. On the contrary, monumental architecture is considered to be a result of and one of several defining traits of civilization.

Some natural resources at Becan, Chichén Itzá, Calakmul, Dzibilchaltún, and elsewhere appear to be spatially dominated by a segment of society, as evidenced by a preponderance of vaulted domestic and administrative structures in close proximity to available water resources. Becan and Chichén Itzá appear to present the best cases for defining certain water features as controlled or semi-controlled resources. At Becan, the central precinct is enclosed by a moat, breeched only by bridges leading to seven radial causeways. One depression

inside the moat appears to have been culturally modified to reduce seepage and enhance water storage capacity. There are no *chultunes* in the central precinct suggesting water from either the *aguada* and/or the moat was used for consumption. Outside the moat, *chultunes* are evenly distributed throughout the settlement. The Becan data suggest resources inside the moat might have been controlled and resources outside the moat were communal. At Chichén Itzá, the area within 500 meters of *Cenote Xtoloc*, the principal source of water in the central precinct, is dominated by monumental vaulted administrative and elite architecture. One *chultun* exists in the area but it is located off of the main plaza. *Chultun* densities in a concentric zone between 500 meters and one kilometer away from the *cenote* exceed greater than seven per kilometer. Beyond one kilometer from the *cenote*, *chultun* densities decline to below one per kilometer. Interestingly, the 500-meter distance noted at Chichén Itzá repeated at several other sites suggesting that this measurement might approach the limits for energy investment to transport water versus energy invested in construction of *chultunes* or employ another strategy for water procurement. At Dzibilchaltún, some of the highest densities of vaulted architecture occur in close proximity to *Cenote Xlacah*. The evidence suggests that access to certain natural resources

at these sites might have been controlled or partially controlled by a particular segment of society. Other groups had to construct wells or *chultunes* or transport water to cope with a lack of natural resources in the area.

In spite of evidence for preferential access to water resources, Wittfogel's ideas about the causal relationship between water management and the rise of complex society find little support in archaeological evidence. Even the concept of state as it might apply to ancient Maya society seems somewhat problematic and continues to be debated by scholars. Without extensive focused excavations to develop chronological sequences in each portion of the canal systems, *aguadas*, and structures or platforms in the central precinct at sites like Calakmul, we are hard-pressed to completely rule out Wittfogel's hypothesis.

An evolutionary mechanism in a multivariate milieu such as Flannery's (1968, 1972) concept of "linearization" might better explain instances such as the consolidation through time of separate canals serving small communities into a managed network serving an entire site. Control and maintenance of canals or constructions under the jurisdiction of local community leaders would have been appropriated by higher-order controls such as a manager whose authority was grounded in a

centralized political structure. At present, the available data suggest that large-scale canal systems as well as maintenance of *aguadas* in the Maya Lowlands should be considered one of many defining traits of complex society, an effect rather than cause.

I used the project GIS to quantify the distribution of major sites in the study area but found no compelling evidence in support of Carneiro's circumscription. Although clear evidence for warfare exists, insufficient evidence exists to suggest that water resource circumscription was the principal basis for wars of conquest and expansion. The evenly spaced pattern of upper-order sites throughout the peninsula suggests that certain physical and social factors including but not limited to the size of sustainability areas governed the distribution of major urban centers. Since water was one of several factors that determined carrying capacity, an argument could be made that partial consideration of Carneiro's ideas is appropriate to explain the relationship between environment and the ranked distribution of archaeological sites across the peninsula. However, the model does not find further support in the archaeological record for a linear progression from environmental shortfall to social circumscription, to warfare for conquest and the ultimate rise of complex society. The

evidence from this study and existing research demonstrates that the Maya inhabited most of the peninsula with little consideration given to available water. Essentially they were able to solve problems related to water. So, warfare prompted by the control of water is highly unlikely.

Agricultural potential throughout the Yucatán appears to be less variable than the distribution of water. Thus from the perspective of agricultural potential, the environment is a centrifugal force serving to disperse populations, and similar technologies should occur throughout the entire region. Contrastingly, water resources and those conditions mentioned above as the defining physical criteria of ecological zones, climate, subsurface geology, the location of faults and fractures, extent of solution processes, the age of geological formations, variation in relief, and depth to aquifer, produced specific clusters of cultural responses. To test whether or not I could predict the types of adaptive options available at a particular site using environmental factors and a given level of technological competence as the known variable, I standardized the occurrence of adaptive strategies based upon calculated site area derived from the project GIS. In Chapter five, I demonstrated that certain environmental factors provide predictable hydrological options and are indicators of the

types of adaptive strategies expected at ancient settlements.

If technology changed, options changed as well.

As predicted, I discovered significant variability within the physiological districts as defined by Wilson (1980).

Wilson's classification provides a broad environmental framework for comparison and is sufficient for making generalizations about what to expect in a particular area; but are somewhat general to be useful for predicting specific adaptive profiles. I augmented Wilson's districts to include sub-district level data on climate type, annual rainfall, evapotranspiration and water deficit, relief, and surface and subsurface hydrology, then predicted what types of adaptive options the ancient Maya inhabitants would have had available to them based upon their stone-tool technology.

For example, wells provided a year-round supply of water and would have been preferred over storage systems. Considering the clear advantages of wells over *chultunes*, wells should be found wherever excavation to the perched aquifer was feasible. In the Chichén Itzá District, surface depth to the phreatic varies from less than five meters near the coastal zone to more than 35 meters in southern sections. Wells are more abundant at sites located in northern portions of the area whereas sites to the south have none. Dzibilchaltún, a site located in the

Merida District where measurements from the ground surface to the phreatic average five meters or less, has over 100 wells.

Calculated densities of wells per square kilometer of site area decrease as *chultun* densities increase. The northwestern Yucatán Peninsula has the highest densities of wells in the region. Low annual rainfall in addition to proximity of the aquifer makes wells favorable and chultunes dysfunctional. The maximum depth of 35 meters in the Chichén Itzá District appears to exceed the potential for excavation of wells using ancient Maya stone-tool technology. In the Puuc or Sierrita de Ticul and Bolonchen Districts, both inland districts, depths to phreatic range from 30 to over 100 meters. At Uxmal and Sayil, *chultunes* supplemented *aguadas*. Sayil's 307 *chultunes* (McAnany 1990) cover an area of approximately 3.244 square kilometers and have a calculated density of 94.636 per square kilometer. There are no ancient wells at Sayil. Subsequent comparisons of adaptive strategies were based upon observations within eight of the 14 districts defined by Wilson.

Percentages of vessel shapes by total collection, physiographic district, site, water-feature, and associated settlement unit were compared. In addition to calculating frequencies by shape and context, ceramic complex and type were used to develop approximate date ranges for usage of water

features surveyed in the field. Usage chronologies were compared to known site chronology. In all cases, dates for water contexts were consistent with established site chronologies.

Spatial analysis of ceramics collected during fieldwork provided information about the relationship between form and context. Pottery was collected from 13 contexts defined as hydrological or water-features. These included *aguadas*, *akalchens*, *buktes*, canal, caves, *cenotes*, *chultunes*, cisterns, *haltunes*, lakes, *rejolladas*, *sartenejas*, springs, and wells. Artifacts collected at altars, groups, household spaces, mounds, paths, platforms, causeways, structures, terraces, and towers were considered to be in non water-feature contexts.

Pottery collected from five types of water-features, *aguadas*, *cenotes*, *chultunes*, *rejolladas*, and wells accounts for 94.27 percent of all pottery specimens recovered from water-feature contexts. Two types of water-features, *chultunes* and wells, represent 59.27 percent of the total collection recovered from this context. Platforms and structures produced 47.31 percent of the collection from non-hydrological contexts.

Five shapes, basins, flat-base bowls, grater tripod bowls, round ring-stand-base bowls, and jars account for 96.35 percent of the entire collection consisting of 26 different forms. Four

vessel shapes, basins, flat-base bowls, round ring-stand-base bowls, and jars account for 95.92 percent of pottery recovered in hydrological contexts. Of this total, jars account for 70.96 percent. Five shapes, basins, flat-base bowls, grater tripod bowls, round ring-stand-base bowls, and jars account for 96.46 percent of the collection taken from non water-feature contexts. Five vessel shapes, cups, flat-base dish-bowls, inverted Z-lip jars, medial angle bowls, and soup bowls were found exclusively in water-feature contexts. Five shapes, cylindrical vases, tripod jars, miniature round-base bowls, miniature jars (*ollitas*), and pear-shaped vases were collected in other contexts, none classified as water-features. Exclusive vessel shapes account for 1.46 percent of the water-feature collection and 0.32 percent of pottery collected in non-hydrological contexts.

Jars dominated the collection from water features. Three of seven vessel shapes, basins (10.98 percent), flat-base bowls (19.08 percent) and jars (56.65 percent) total 86.71 percent of pottery collected in *aguadas*. Two shapes out of three, bowls grater-tripod, and jars represent 96.42 percent of all pottery found in *akalchens*. If frequency suggests versatility, jars represent the most functional and versatile vessel shape. They were used to collect, capture, store, and transport water as

well as other substances. The second most frequent shape in all contexts is flat-base bowls. These were most likely used in food preparation and service. Two shapes, flat-base bowls and jars dominate collections from canals, caves, *cenotes*, and wells totaling 77.28, 91.67, 93.33, and 85.91 percent of each collection by feature respectively. In one context, cisterns, flat-base bowls and jars were the only two shapes recovered.

Diversity in collections, measured by the number of different shapes represented in collections from each context, varied considerably, ranging from two shapes from cisterns to fifteen from structures. For water features, the collection from *chultunes* was most diverse, containing twelve different forms.

In general, non water-feature contexts measured higher amounts of diversity in form. In collections from causeways and towers, flat-base bowls and jars accounted for 93.85 percent and 92.68 percent respectively. Three vessel shapes, basins, flat-base bowls, and jars totaled 94.42 percent and 90.87 percent respectively of collections from solitary platforms and unclassified structures. In small architectural groups, flat-base bowls, round ring-stand base bowls, and jars accounted for 93.33 percent of the collection.

How does the ceramic evidence inform us about the ancient Maya and their use of water resources? Predictably, my collection suggests that certain vessel shapes are linked to particular functional spaces. When considering vessel form, collections from water contexts were only slightly less diverse than those taken from associated architectural contexts. A higher incidence of non-utilitarian ceramics exists in non-water feature contexts. If we assume a more-limited set of activities, for example gathering water only, took place around or close to water features compared to residential spaces, we should find less diversity in the pottery collected from water features. The slight variation in my collection suggests household chores were accomplished at or near water features.

The spatial data indicate a tripartite relationship between an assemblage consisting of utilitarian ceramics and non-ceramic artifacts, water-features, and domestic space. In addition to the presence of utilitarian ceramics and other artifact classes in these contexts, a majority of the *chultunes* and wells are situated near or adjacent to domestic or habitations or platforms thereby forming functional components of residential space. In certain instances, Uxmal and Sayil for example, the relationship applies to elite residential structures and palaces as well. However, elites might not have

been as concerned with proximity of water storage or extraction features as non-elite residents. The results of this research suggest that traditional definitions of elite residential space do not always require immediate water sources.

This project provided an opportunity to test methods I developed to recover spatial and non-spatial information from publications and paper maps by converting the data into digital format. I designed and deployed a project geographical information system to query spatial relationships and to explore the functional processes responsible for them. This method involves completion of a series of procedures alternating between laboratory and field.

I scanned existing maps, some published more than 75 years ago, and converted them into raster digital data. Identifiable architectural elements and natural features on the scanned maps were selected as ground control points for geo-referencing. In the field, geographic coordinates for pre-selected map elements were collected using a Trimble GeoExplorer III GPS data collector. Map elements were then registered with their complementary ground control positions in the project GIS. To verify accuracy of the registration process, additional map features were selected from registered maps for ground truth. In those instances where no maps were available, sites were

either GPS mapped or mapped with a Laser Total Station. After the registration process was completed and precision tested, non-spatial and spatial information from published maps and the literature were merged with original data to accomplish a variety of problem-oriented goals.

Along with basic instruction in GIS operations, the procedures employed in the execution of this research were incorporated into a course of instruction for higher education taught at the University of Central Florida.

The ceramic collection is being prepared to be turned over to each local INAH office having jurisdiction over the sites in the region. Our collection includes samples from 22 archaeological sites in nine different physical districts. Prior to turning over my ceramics, type collections will be sent to each of the three INAH offices in Campeche, Quintana Roo, and Yucatán for use as reference collections by other researchers working in the Yucatán. The type collection will provide ceramicists with samples for comparative analysis.

Future synthesis of ideas emerging from this research with those from other studies will provide a more comprehensive account of culture processes in ancient Maya society and shed light on the centripetal forces at work in lowland society that gave rise to unequal access, stratification, and centralization

of power in the region. This paper is only the beginning of my attempt to explain the Maya world of water. As expected, I conclude with more questions than I had when I began.

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APPENDIX A

GLOSSARY

- Aguada:* Depressions resulting from the local sinking of limestone. *Aguadas* contain rainwater and sometimes aquifer water. Obstruction may occur by vegetation growth surrounding *aguadas*. Many *aguadas* were culturally modified.
- Aguadita:* A small *aguada* that is found in direct association with a domestic lot.
- Akalche:* A large shoal or flat area where rainwater accumulates is stored for several months. *Akalches* are areas with poor drainage. Decomposition of leaves and fallen trees may cause elevations or hillocks consisting mainly of pure vegetable soil over a bed of clay.
- Akalchen:* In Northwestern Yucatán this term refers to a pool of water in a dark cave. In the area of the site of Coba the term is used to refer to swirl-shafts that penetrate subterranean chambers.
- Bajo:* Swamp or bottomlands often seasonally inundated.
- Cenote:* A collapsed doline or subterranean chamber having a pool of water. Roys 1931 determined there were three types of *cenotes*.

- Chultun:* An underground reservoir, often but not always having a bell-shaped chamber consisting mainly of five parts: catchment's areas including minimum and maximum perimeters, mouth, neck and chamber.
- Haltun:* A small rock collapsing that has a great depth and an access to the surface that allows for rainwater to store. The classification for this feature varies depending on the region. In some areas *haltunes* contain water in all seasons and are springs.
- Rejollada:* A funnel-shaped depression that does not reach the depth of a cenote. Rejolladas are considered to be prime horticultural areas by the modern Maya.
- Sarteneja:* A shallow hole, not larger than 2 meters diameter, usually located on a limestone outcrop that only fills with rainwater.
- Sascab:* A layer of friable marl consisting of nearly pure calcium carbonate.
- Zuhuy ha':* Sacred water.

APPENDIX B

POTTERY

The typology for pottery collected during fieldwork is presented in a modified "short format" style employed by Ball (1978). In addition to its heuristic value, these data are provided to facilitate comparisons with collections taken from other contexts. Gifford (1976) provided an instructive explanation of the type-variety approach.

Although the collection as presented below represents the total ceramics collected from all sites, each site is considered as a discrete unit of analysis in subsequent chapters. Each typological entry includes ancillary information including, ceramic group basis, frequency, number of sherds, counts by vessel shape, inferences regarding the function of specific vessel forms, sherd totals by water feature context, sherd counts for contexts other than water features, site distribution by lot number, and a partial list of the regional distribution with citations for each ceramic group. Each field is described below.

Group: Name of the established ceramic group for each type.

Type-Variety: Types within each group represented in the collection.

Established by: Name of the ceramist/s who first identified and described the type and/or variety, the corresponding year of publication, and page/s where the description appears.

Frequency: total number of sherds collected for each group.

Vessel shape: total number of sherds by shape for each group.

Function: possible use by shape

Water feature context: total sherds collected in water-feature contexts listed by frequency and water feature type.

Other context: total sherds collected in non water-related contexts listed by frequency and feature type.

Lot distribution: a listing by lot number and corresponding archaeological site.

Regional distribution: citations for other sites or collections where this group or types have been identified.

The following describes the ceramics recovered in all contexts during nine months of field survey. In and of itself, each typological entry is instrumental in shaping our ideas and understanding of the relationship between various functional contexts and human activity.

Group: Aguacate

Type-Variety: Ixcanrio Orange Polychrome: Ixcanrio

Established by: (Gifford 1976: 129)

Frequency: 1 sherd

Vessel shape: Bowl flat base tripod (1)

Function: Domestic (bowls as food container or for serving)

Water feature context: 1 sherd (100%) including *aguada* (1)

Other context: None

Lot distribution: 1238 (Dzibanché)

Regional distribution: Coba (Robles Castellanos 1990), Toh caves (Rissolo 2001)

Group: Aguila Orange

Type-Variety: Aguila Orange: Aguila (8)

Aguila Orange: Not identified (4)

Established by: (Smith and Gifford 1966: 154)

Frequency: 12 sherds

Vessel shape: jar (8), bowl flat base (4)

Function: Tradeware, possibly used for elite consumption or household use. For example, jars functioned as water containers and bowls as food containers or serving vessels. Also, used in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 3 sherds (25 %), including *aguada* (2), and *chultun* (1)

Other context: 9 sherds (75%), including structures (9)

Lot distribution: 1225 (Noh Ichmul); 1230 (Xelha); 1238 and 1239 (Dzibanché)

Regional distribution: Mayapan, Uxmal, Kabah, Chichén Itzá
(Perez de Heredia Puente 1999; Smith 1971), Becan (Ball 1977),
Cobá (Robles Castellanos 1990), San Gervasio (Peraza Lope
1993), Playa del Carmen (Perez Rivas 1993), Tacbil-Ha cave
(Rissolo 2001).

Group: Arena

Type-Variety: Arena Red: Arena

Established by: (Robles Castellanos 1990)

Frequency: 33 sherds

Vessel shape: Bowl composite body flat base tripod (28), bowl
round ringstand base (5)

Function: domestic, bowls as food containers or serving
vessels.

Water feature context: 26 sherds (78.78%), including *aguada*
(1), *chultun* (13), well (10), *aktun* (2)

Other context: 7 sherds (21.22%), including architectural group
(5), path (1), structure (1)

Lot distribution: 1181(Cumtun); 1182 (Chichén Itzá); 1190 (Noh
Aktun); 1192, 1196, 1199 and 1217(Coba); 1230(Xelha)

Regional distribution: Coba, Tanchah, and Yaxuna (Brainerd
1958), Tacbil-Ha cave (Rissolo 2001)

Group: Balanza

Type-Variety: Balanza Black: Balanza (5)

Balanza Black: Not identified (2)

Established by: (Smith and Gifford 1966)

Frequency: 7 sherds

Vessel shape: Bowl flat base (7)

Function: Tradeware possibly for elite consumption or domestic use. For example, jars functioned as water containers and bowls as food containers or serving vessels. Also, used in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 7 sherds (100%), including *chultun* (3), *aguada* (3), *cenote* (1)

Other context: none

Lot distribution: 1215 (Acanceh); 1237 (Calakmul); 1238 and 1239 (Dzibanché); 1241 (Kohunlich)

Regional distribution: Mayapan (1971), Komchen (Andrews V 1988), Cobá (Robles Castellanos 1990), Xelha (Canche Manzanero 1992), San Gervasio (Peraza Lope 1993), Toh cave (Rissolo 2001), Becan (Ball 1977)

Group: Becanthen

Type-Variety: Becanthen Brown: Becanthen

Established by: (Ball 1977)

Frequency: 5 sherds

Vessel shape: Jar narrow mouth low neck (5)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 5 sherds (100%) including *aguada* (5)

Other context: None

Lot distribution: 1238 (Dzibanché)

Regional distribution: Becan (Ball 1977), Coba (Robles Castellanos 1990), Chichén Itzá (Perez de Heredia Puente 1999)

Group: Brown Chuburna

Type-Variety: Chuburna Brown: Chuburna

Established by: (Smith 1971)

Frequency: 19 sherds

Vessel shape: jars (18), bowl flat base (1)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 16 sherds (84.21%) including cave (3), cistern (1), *haltun* (1), well (11)

Other context: 3 sherds (15.79%) including mound (1), platform (1), structure (1)

Lot distribution: 1003, 1005, 1006, 1011, 1014 and 1015 (Aké); 1110 and 1119 (Dzibilchaltún)

Regional distribution: Chichén Itzá (Perez de Heredia Puente

1999; Smith 1971), Mayapan (Smith 1971), Komchen (Andrews V 1988), El Vergel (Fernandez del Valle 1992), Aké (Quintal Suaste 1993)

Group: Buff Maxcanu

Type-Variety: Maxcanu Buff: Maxcanu (10)

Maxcanu Buff: Not Identified (2)

Tacopate Trickle-on-Brown: Tacopate (9)

Hunabchen Orange: Hunabchen (1)

Established by: (Smith 1971)see also (Ball 1977)

Frequency: 22 sherds

Vessel shape: Basin (5), bowl flat base (2), jar (15)

Function: Domestic, jars for water or grain storage, bowls as food containers or serving vessels, and basins for food preparation.

Water feature context: 22 sherds (100%) including *aguada* (9), *akalchen* (1), *cañada* or canal (2), *chultun* (10)

Other context: None

Lot distribution: 1185 (*Akalchen*); 1181 (Chichén Itzá); 1238 and 1239 (Dzibanché); 1205 (Edzná); 1240 (Kohunlich)

Regional distribution: Becan (Ball 1977), Toh 2 and Tabi Ha 3 caves (Rissolo 2001), Holactun, Maxcanu, and Mayapan (Smith 1971)

Group: Buff Polbox

Type-Variety: Polbox Buff: Polbox (10)

Tecoh Red-on-Buff: Tecoh (3)

Established by: (Smith 1971)

Frequency: 13 sherds

Vessel shape: jar (13)

Function: Domestic, jars for water or grain storage.

Water feature context: 12 sherds (92.31%) including *chultun* (1), *cenote* (11)

Other context: 1 sherd (7.69%) including platform (1)

Lot distribution: 1152 and 1182 (Chichén Itzá); 1016 and 1017 (Mayapan); 1123 (Yula)

Regional distribution: Acanceh, Mani, and Mayapan (Smith 1971), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971)

Group: Carolina

Type-Variety: Carolina Bychrome-Incised: Carolina

Established by: Robles 1988: 66 (Robles Castellanos 1988)

Frequency: 2 sherds

Vessel shape: Bowl flat base (1), jar (1)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 1 sherd (50%) including well (1)

Other context: 1 sherd (50%) including architectural group (1)

Lot distribution: 1196 (Coba), 1190 (Noh Aktun)

Regional distribution: Isla Cerritos (Robles Castellanos 1988), Cobá (Robles Castellanos 1990); Ek Balam (Bey III et al. 1998), Tancah, Kantunilkin, Chiquilá, and Leona Vicario (Sanders 1960), Xelha (Canche Manzanero 1992); Yucatán-Campeche Coast (Ball 1978), San Gervasio (Peraza Lope 1993), Yaxuna (Brainerd 1958:120), El Naranjal (Boucher 1997), Grupo Chan Pich, Toh, Pech, and Pak Chen caves (Rissolo 2001), T'isil (Ceja Acosta 2000)

Group: Cetelac

Type-Variety: Cetelac Fiber-temper: Cetelac

Established by: (Smith 1971)

Frequency: 2 sherds

Vessel shape: Bowl round ringstand base (2)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 1 sherd (50%) including *aguada* (1)

Other context: 1 sherd (50%) including structure (1)

Lot distribution: 1188 (Coba); 1163 (Chichén Itzá)

Regional distribution: Dzibilchaltún, Yaxuna, and Coba (Brainerd 1958), Holkotun (Ball 1978), El Meco (Andrews and Robles Castellanos 1986), Playa del Carmen and Tancah (Robles Castellanos 1990), Chichén Itzá (Perez de Heredia Puente 1999);

Toh, Tacbil Ha, Pech, and Pak Chen caves (Rissolo 2001)

Group: Colonial Not Identified

Type-Variety: Colonial with Brownish-yellow interior slip (1)

Colonial Not Identified (1)

Frequency: 2 sherds

Vessel shape: Cup (1), jar (1)

Function: Domestic, jars for water or grain storage and cups as food containers or serving vessels.

Water feature context: 1 sherd (50%) including well (1)

Other context: 1 sherd (50%) including structure (1)

Lot distribution: 1115 (Dzibilchaltún); 1226 (Noh Ichmul)

Group: Chablekal

Type-Variety: Chablekal Fine Gray: Chablekal

Established by: (Smith 1971)

Frequency: 4 sherds

Vessel shape: vase flat base (4)

Function: Tradeware, possibly used for elite consumption. Vases functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 1 sherd (25%) including well (1)

Other context: 3 sherds (75%) including structure (3)

Lot distribution: 1221 (Acanmul); 1118 (Dzibilchaltún); 1022 (Mayapan)

Regional distribution: Acanceh, Calcetok, Chichén Itzá, Dzebtun, Holactun, Kabah, Labná, Sayil, Sotuta, Uxmal (Smith 1971), El Meco (Andrews and Robles Castellanos 1986), Komchen (Andrews V 1988), Isla Cerritos (Robles Castellanos 1988), Cobá (Robles Castellanos 1990), Xelha (Canche Manzanero 1992), El Vergel (Fernandez del Valle 1992), San Gervasio (Peraza Lope 1993), Aké (Quintal Suaste 1993), Chichén Itzá (Perez de Heredia Puente 1999)

Group: Chatel

Type-Variety: Chatel Orange-on-Red: Chatel

Established by: (Forsyth 1983)

Frequency: 3 sherds

Vessel shape: Bowl flat base (2), jar (1)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 3 sherds (100%) including *chultun* (3)

Other context: None

Lot distribution: 1205 (Edzná)

Regional distribution: None cited

Group: Cream Kukula

Type-Variety: Kukula Cream: Kukula (8)

Xcanchakan Black-on-Cream: Xcanchakan (11)

Established by: (Vaillant 1927); (Smith 1971); see also (Ochoa Rodriguez 1999)

Frequency: 19 sherds

Vessel shape: Jar (18), bowl round ringstand base (1)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels. Also used in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 4 sherds (21.05%) including *cenote* (1), well (1), *chultun* (1), *rejollada* (1)

Other context: 15 sherds (78.95%) including *sacbe* (1), structure (14)

Lot distribution: 1221 (Acanmul); 1002 and 1009 (Aké); 1156 (Chichén Itzá); 1110 (Dzibilchaltún); 1203 (Isla Cerritos); 1046 (Uxmal)

Regional distribution: Acanceh, Mani, Mayapan, Cerro Obscura, *Cenote Telchaquillo*, Oxkutzcab, Ucu, Dzab Ná, Hunactí, Kizil, Colonial Miraflores, San Benito Fortress, and Yacman (Brainerd 1958), San Miguel and San Gervasio Cozumel, Mulchí, Vista Alegre, Monte Bravo, Tulum, Tancah, and Ichpaatun (Sanders 1960), Mayapan (Smith 1971), Dzibilchaltún (Andrews IV 1960,

1980; Brainerd 1958; Maldonado Cardenas 1999; Ochoa Rodriguez 1995; Simmons 1979), El Vergel II (Fernandez del Valle 1992), El Olimpo building (Burgos V 1990), Cholul (Pool Cab 1997), Aké (Quintal Suaste 1993); Chichén Itzá (Brainerd 1958; Cobos Palma 1997; Fernandez Sousa 1996; Lincoln 1990b; Ochoa Rodriguez 1995; Peraza Lope 1993; Perez de Heredia Puente 1999; Ruppert et al. 1954; Winemiller 1997), Uxmal (Kurjack, Maldonado Cardenas and Green Robertson 1989; Maldonado Cardenas 1979), Oxkintok (Varela Torrecilla 1996), Xelha (Canche Manzanero 1992), Playa del Carmen (Gonzalez de la Mata and del Carmen Trejo A. 1981; Peraza Lope 1993) El Meco (Andrews and Robles Castellanos 1986), Xcambo (Jimenez Alvarez, Ceballos Gallareta and Sierra Sosa in press), Cobá (Robles Castellanos 1990), Xkipché, Isla del Carmen (Ruz Lhullier 1969), Gruta de Chaac (Andrews IV 1965b), and Kabah (Smith 1971)

Group: Dos Arroyos

Type-Variety: Dos Arroyos Orange Polychrome: Dos Arroyos (12)

San Blas Red-on-Orange: San Blas (2)

Established by: (Smith and Gifford 1966)

Frequency: 14 sherds

Vessel shape: Bowl flat base (13), jar (1)

Function: Tradeware, possibly used for elite consumption or domestic use. For example, jars functioned as water containers

and bowls as food containers or serving vessels. Also, used in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 11 sherds (78.57%) including *aguada* (10), *chultun* (1)

Other context: 3 sherds (21.43%) including structure (3)

Lot distribution: 1238 and 1239 (Dzibanché), 1225 (Noh Ichmul), 1122 (Yula)

Regional distribution: Becan (Ball 1977), Dzibilnocac (Nelson 1973), Mani, Kabah, and Mayapan (Brainerd 1958), Toh cave (Rissolo 2001)

Group: Dzilam

Type-Variety: Dzilam Green-Incised: Dzilam (1)

Established by: (Robles Castellanos 1990)

Frequency: 1 sherd

Vessel shape: bowl outcurving sides flat base (1)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 1 sherd (100%) including *cenote* (1)

Other context: None

Lot distribution: 1215 Acanceh

Regional distribution: Coba, Dzilam de Bravo, and Yaxuna
(Robles Castellanos 1990), Tancah (Sanders 1960), Toh, Pech,
and Pak Chen caves (Rissolo 2001)

Group: Dzudzuquil

Type-Variety: Dzudzuquil Cream: Dzudzuquil (2)

Kuche Incised: Kuche (1)

Established by: Andrews V 1988:21-23 (Andrews V 1988)

Frequency: 3 sherds

Vessel shape: Bowl flat base (3)

Function: Domestic, bowls as food containers or for serving
vessels.

Water feature context: 2 sherds (66.66%) including *rejollada*
(1), *chultun* (1)

Other context: 1 sherd (33.33%) including structure (1)

Lot distribution: 1169 (Chichén Itzá); 1044 (Uxmal); 1055
(Nohpat)

Regional distribution: Komchen (Andrews V 1988), Ek Balam
(Bey III et al. 1998), Loltun (Gonzalez Licon 1986; Robles
Castellanos 1997), Yaxuna (Suhler, Arden and Johnstone 1988),
Toh and Pech caves (Rissolo 2001)

Group: Encanto

Type-Variety: Encanto Striated: Encanto (24)

Encanto Striated: Yokat (30)

Encanto Striated: Sacna (37)

Established by: (Smith and Gifford 1966); (Robles Castellanos 1990)

Frequency: 91 sherds

Vessel shape: Jar (91)

Function: Domestic, used for water transport, capture, storage, and household tasks such as washing articles or bathing.

Water feature context: 57 sherds (62.64%) including *aguada* (22), *aktun* (3), *cañada* or canal (10), *chultun* (16), well (4), *sartenejas* (2)

Other context: 34 sherds (37.36%) including architectural group (17), path (2), platform (8), structure (7)

Lot distribution: 1186, 1187, 1188, 1192, 1193, 1196, 1199, 1217, and 1231 (Coba); 1190 (Noh Aktun); 1238 and 1239 (Dzibanché); 1240 (Kohunlich); 1225 (Noh Ichmul); 1093 (Sacbe Uxmal-Nohpat); 1230 (Xelha)

Regional distribution: Becan (Ball 1977), Coba (Robles Castellanos 1990), Xelha (Canche Manzanero 1992)

Group: Fine Orange Balancan

Type-Variety: Balancan Fine Orange: Balancan (3)

Balancan Fine Orange: Not identified (1)

Established by: (Smith 1971)

Frequency: 4 sherds

Vessel shape: jar (2), bowl outcurving sides flat base (1), not identified (1)

Function: Tradeware, possibly used for elite consumption or domestic use. For example, jars functioned as water containers and bowls as food containers or serving vessels. Also, used in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 2 sherds (50 %), including *chultun* (2)

Other context: 2 sherds (50%), including structure (2)

Lot distribution: 1203 (Isla Cerritos); 1204 (Edzná); (1024) Mayapan; 1060 (Nohpat)

Regional distribution: Acanceh, Holactun, Kabah, Labná, Mayapan, Sayil, Uxmal, and Xcanatun (Smith 1971), El Meco (Andrews and Robles Castellanos 1986), Komchen (Andrews V 1988), Isla Cerritos (Robles Castellanos 1988), Uxmal (Maldonado Cardenas, Kurjack and Green Robertson 1989), Canbalam, Edzná, and Jaina (Ruz Lhullier 1945), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971), Becan (Ball 1977)

Group: Fine Orange Matillas

Type-Variety: Matillas Fine Orange: Matillas (3)

Salto Composite: Salto (1)

Established by: (Smith 1971)

Frequency: 4 sherds

Vessel shape: Jar (4)

Function: Tradeware, possibly used for elite consumption. Might have functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 4 sherds (100%) including *chultun* (3), *cenote* (1)

Other context: None

Lot distribution: 1162 (Chichén Itzá); 1048 (Uxmal); 1026 (Mayapan)

Regional distribution: Mayapan (Smith 1971), El Meco (Andrews and Robles Castellanos 1986; Sanders 1960), Xelha (Canche Manzanero 1992), San Gervasio (Peraza Lope 1993), Playa del Carmen (Perez Rivas 1993) Dzibilchaltún (Ochoa Rodriguez 1995; Smith 1971); Tancah, Tulum Yuukluuk, El Rey, Cancun, Vista Alegre, Mulchil (Sanders 1960); Coba (Robles Castellanos 1990), Champoton and Tixchel (Ruz Lhullier 1969); Aguacatal and Atasta (Matheny 1970; Ruz Lhullier 1969)

Group: Fine Orange Silho

Type-Variety: Silho Fine Orange: Silho (38)

Cumpich Incised: Cumpich (2)

Established by: Smith and Gifford 1966: 173 (Smith and Gifford 1966)

Frequency: 40 sherds

Vessel shape: bowl flat base (11), bowl round base (2), jar pear-shaped body (1), jar (24), vase pear-shaped body (1), not determined (1)

Function: Tradeware, possibly used for elite consumption. Might have functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 10 sherds (25%) including *chultun* (10)

Other context: 30 sherds (75%) including platform (8), structure (22)

Lot distribution: 1221 (Acanmul); 1129, 1150, 1152, 1161, 1162, and 1177 (Chichén Itzá); 1181 (Cumtun); 1203 (Isla Cerritos); 1122 (Yula)

Regional distribution: Mayapan (Smith 1971), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971; Winemiller 1997), El Meco (Andrews and Robles Castellanos 1986), Komchen (Andrews V 1988), Isla Cerritos (Robles Castellanos 1988), Uxmal (Maldonado Cardenas, Kurjack and Green Robertson 1989), Xelha (Canche Manzanero 1992), El Vergel (Fernandez del Valle 1992), San Gervasio (Peraza Lope 1993), Becan (Ball 1977)

Group: Flor

Type-Variety: Flor Cream: Flor (1)

Flor Cream: Not Identified (1)

Mateo Red on Cream: Mateo (4)

Established by: (Smith 1971)

Frequency: 6 sherds

Vessel shape: Jar wide mouth low neck (2), bowl rounded
incurving sides, outsloping rim flat base (4)

Function: Domestic, jars for water or grain storage and bowls
as food containers or serving vessels.

Water feature context: 6 sherds (100%) including *chultun* (2),
aguada (4)

Other context: None

Lot distribution: 1238 (Dzibanché); 1064 (Sayil); 1206 (Edzná)

Regional distribution: Mayapan (Smith 1971), Becan (Ball 1977),
Komchen (Andrews V 1988), Xelha (Canche Manzanero 1992),
Dzibilchaltún (Ochoa Rodriguez 1995), Chichén Itzá (Perez de
Heredia Puente 1999)

Group: Huachinango

Type-Variety: Huachinango Bychrome-Incised: Huachinango

Established by: Ball 1978: 110 (Ball 1978)

Frequency: 2 sherds

Vessel shape: Bowl flat base (2)

Function: Domestic, bowls as food containers or for serving
vessels.

Water feature context: None

Other context: 2 sherds (100%) including structure (2)

Lot distribution: 1221 (Acanmul)

Regional distribution: Coba (Robles Castellanos 1990), Chicxulub, Diana Milan, and Dolores (Ball 1978) Isla Cerritos (Brainerd 1958), Tancah (Sanders 1960), Chichén Itzá (Perez de Heredia Puente 1999); Toh, Pech, and Tam Ha caves (Rissolo 2001)

Group: Impreso por transferencia bajo el vidriado (White fine ware)

Type-Variety: Modelado Estampe Feston 39 (1)

Red and Blue Flowers on White (3)

Established by: Burgos 1995: 198-201 and 242-244 (Burgos V 1990)

Frequency: 4 sherds

Vessel shape: Soup bowl (2), cups (2)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 4 sherds (100%) including cenote (1), well (3)

Other context: None

Lot distribution: 1215 (Acanceh), 1115 (Dzibilchaltún)

Regional distribution: Merida, Aké, Progreso, Mama, Izamal, Rancho el Colorado, Campeche City (Burgos V 1990)

Group: Joventud

Type-Variety: Joventud Red: Joventud

Established by: (Adams 1971)

Frequency: 1 sherd

Vessel shape: Bowl flat base (1)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: None

Other context: 1 sherd (100%) including platform (1)

Lot distribution: 1213 (Edzná)

Regional distribution: Holactun, Kabah, Xpuhil and Mani *Cenote* (Brainerd 1958), Becan (Ball 1977; Brainerd 1958), Santa Rosa Xtampak, Dzibilnocac, Chacchob, Dzibilchaltún (Ball 1977), Chichén Itzá (Perez de Heredia Puente 1999), Toh and Pech caves (Rissolo 2001)

Group: K'inich

Type-Variety: K'inich Orange: K'inich (1)

Dzilam Orange: Not Identified (1)

Established by: Simmons no date: 130-132 (Simmons 1973, 1979); see also Boucher and Palomo (n.d.)

Frequency: 2 sherds

Vessel shape: jar (1), bowl flat base (10)

Function: Domestic, jars for water or grain storage, bowls as food containers or serving vessels, and basins for food preparation. In some instances ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 2 sherds (100%) including cave (1), *chultun* (1)

Other context: None

Lot distribution: 1005 (Aké); 1057 (Nohpat)

Regional distribution: Cobá (Robles Castellanos 1990), Uxmal, Sayil, Kabah, Xoclán (Boucher n.d.), Dzibilchaltún (Ochoa Rodriguez 1995)

Group: Molino

Type-Variety: Infierno Black: Infierno also known as Molino Negro: Buitre

Established by: (Ball 1977)

Frequency: 6 sherds

Vessel shape: Bowl flat base (6)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 6 sherds (100%) including *aguada* (4), *cañada* or canal (2)

Other context: None

Lot distribution: 1238 (Dzibanché); 1240 (Kohunlich)

Regional distribution: Becan (Ball 1977)

Group: Muxanal

Type-Variety: Muxanal Red-on-Cream: Muxanal

Established by: Ball 1977: 48 (Ball 1977)

Frequency: 1 sherd

Vessel shape: Bowl outsloping flaring sides flat base (1)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 1 sherd (100%) including *chultun* (1)

Other context: None

Lot distribution: 1060 (Nohpat)

Regional distribution: Becan and Dzibilchaltún (Ball 1977),
Dzibilnocac (Nelson 1973), Yaxuna and Mani (Brainerd 1958),
Chichén Itzá (Perez de Heredia Puente 1999)

Group: Nimun

Type-Variety: Nimun Brown: Nimun

Established by: Simmons no date: 8-10 (Simmons 1973, 1979)

Frequency: 2 sherds

Vessel shape: jar (2)

Function: Domestic, used for water transport, capture, storage, and household tasks such as washing articles or bathing.

Water feature context: 1 sherd (50%) including *chultun* (1)

Other context: 1 sherd (50%) including structure (1)

Lot distribution: 1221 (Acanmul); 1054 (Uxmal)

Regional distribution: Dzibilchaltún (Simmons 1973, 1979), Jaina, la Pitaya, Rancho San Juan and Cakamaax (Williams Beck 1999)

Group: Not Identified

Frequency: 24 sherds

Vessel shape: Bowl flat base (14), bowl flat base tripod (1), bowl round base (1), jar 7), not determined (1)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 11 sherds (45.83 %) including *aguada* (1), *cañada* or canal (1), *cenote* (1), cave (1), *chultun* (5), well (2)

Other context: 13 sherds (54.17 %) including mound (1), platform (3), structure (2), tower (1), *sacbe* (6)

Lot distribution: 1009 and 1011 (Aké); 1124 (Chichén Itzá); 1219 (Coba); 1181 (Cumtun); 1238 (Dzibanché); 1108 and 1119 (Dzibilchaltún); 1213 (Edzná); 1240 (Kohunlich); 1021

(Mayapan); 1081, 1084, 1087, 1089, and 1091 (Sacbe Uxmal-Nohpat); 1042 (Uxmal); 1122 (Yula)

Group: Paxyan

Type-Variety: Paxyan Black-on-Grey: Paxyan

Established by: Forsyth 1983: 126-128 (Forsyth 1983)

Frequency: 1 sherd

Vessel shape: bowl flat base (1)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 1 sherd (100%) including *chultun* (1)

Other context: None

Lot distribution: 1204 (Edzná)

Regional distribution: Edzná (Forsyth 1983)

Group: Pital

Type-Variety: Pital Cream: Pital

Established by: (Adams 1971)

Frequency: 1 sherd

Vessel shape: Jar (1)

Function: Domestic, used for water transport, capture, storage, and household tasks such as washing articles or bathing.

Water feature context: 1 sherd (100%) including *chultun* (1)

Other context: None

Lot distribution: 1206 (Edzná)

Regional distribution: Dzibilchaltún and Becan (Ball 1977), Toh cave (Rissolo 2001), Chichén Itzá (Perez de Heredia Puente 1999)

Group: Plumbate Tohil

Type-Variety: Tohil Plumbate: Tohil (4)

Tumbador Incised: Tumbador (1)

Porvenir Gadrooned: Porvenir (1)

Established by: (Smith 1971)

Frequency: 6 sherds

Vessel shape: Jar (4), bowl flat base (2)

Function: Domestic, jars for water or grain storage, bowls as food containers or serving vessels, and basins for food preparation. In some instances ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 2 sherds (33.33%) including *chultun* (2)

Other context: 4 sherds (66.66%) including structure (4)

Lot distribution: 1129 and 1149 (Chichén Itzá); 1122 (Yula)

Regional distribution: Widely distributed along Mesoamerica. In the Yucatán Peninsula, Tohil Plumbate group has been reported at Jaina, Uaymil, Isla Piedras, Champoton, and Isla del Carmen (Smith 1971), Can Balam (Ball 1978), Dzibilchaltún (Andrews IV

1958, 1960, 1980; Ball 1978), Isla Cerritos (Andrews et al. 1986; Ball 1978), Uxmal (Brainerd 1958; Kowalski et al. 1996), Mani, Dzebtun, Zumpulche (Brainerd 1958), Chichén Itzá (Brainerd 1958; Morris, Charlott and Axtell Morris 1931; Perez de Heredia Puente 1999; Ruppert 1935; Smith 1971); Kabah (Smith 1971); Becan, Chicana (Ball 1977); Wild Cane Cay (Kidder 1954)

Group: Polvero

Type-Variety: Polvero Black: Polvero

Established by: Smith 1971: 24 (Smith 1971)

Frequency: 1 sherd

Vessel shape: Bowl outcurving sides flat base (1)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: None

Other context: 1 sherd (100%) including platform (1)

Lot distribution: 1108 (Dzibilchaltún)

Regional distribution: Mayapan (Smith 1971), Becan (Ball 1977), Komchen (Andrews V 1988, 1993), Xelha (Canche Manzanero 1992), El Vergel (Fernandez del Valle 1992), Aké (Quintal Suaste 1993), Dzibilchaltún (Ochoa Rodriguez 1995), Toh cave (Rissolo 2001)

Group: Red Baca

Type-Variety: Baca Red: Baca

Established by: Simmons no date: 3-5 (Simmons 1973, 1979)

Frequency: 3 sherds

Vessel shape: Bowl flat base (3)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 3 sherds (100%) including *chultun* (3)

Other context: None

Lot distribution: 1046 (Uxmal)

Regional distribution: Dzibilchaltún (Simmons 1973, 1979), Jaina (Piña Chan 1968); Yucatán West coast from Campeche city to Progreso, Yucatán (Ball 1978); Dzehkabtun, Zohchen, Nohcacab, Chenchán, Oxpechen, and Dzibiltun (Williams Beck 1999)

Group: Red Batres

Type-Variety: Batres Red: Batres (58)

Batres Red: Not Identified (5)

Lakin Composite-Impressed: Lakin (2)

Coba Composite: Coba (1)

Established by: (Smith 1971); (Robles Castellanos 1990)

Frequency: 66 sherds

Vessel shape: Basin (5), bowl flat base (8), bowl round ringstand base (4), dish flat base (2), jar (46), not determined (1)

Function: Domestic, jars for water or grain storage, bowls and dishes as food containers or serving vessels, and basins for food preparation.

Water feature context: 50 sherds (75.75%) including *aguada* (10), *cañada* or canal (5), *chultun* (3), well (3), *rejollada* (1), *cenote* (28)

Other context: 16 sherds (24.26%) including structure (8), sacbe (1), path (2), architectural group (5)

Lot distribution: 1221 (Acanmul); 1002 (Aké); 1175 (Chichén Itzá); 1196, 1199, 1231, and 1236 (Coba); 1238 (Dzibanché); 1110 and 1117 (Dzibilchaltún); 1203 (Isla Cerritos); 1240 and 1241 (Kohunlich); 1055 (Nohpat); 1190 (Noh Aktun); 1092 (Sacbe Uxmal-Nohpat); 1043 (Uxmal); 1230 (Xelha)

Regional distribution: Coba, Yaxuna and Oxkintok (Brainerd 1958), Tancah and Coba (Robles Castellanos 1990), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971), Acanceh, Mayapan and Yaxuna (Smith 1971), Toh caves (Rissolo 2001)

Group: Red Dzibiac

Type-Variety: Dzibiac Red: Dzibiac (81)

Chan Kom Black-on-Red: Chan Kom (1)

Holtun Gouged-Incised: Holtun (3)

Xuku Incised: Xuku (5)

Xuku Incised: Cream Slip (1)

Established by: (Smith 1971)

Frequency: 91 sherds

Vessel shape: Basin (1), bowl flat base (46), bowl flat base tripod (3), grater tripod (4), bowl round base (2), jar (33), jar pear-shaped body (1)

Function: Domestic, jars used for water or grain storage, and bowls as food containers or serving vessels, basins, and grater for food preparation. Jars pear-shaped body and bowls in some instances functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 25 sherds (27.47%) including *chultun* (12), well (8), *rejollada* (5)

Other context: 66 sherds (71.43%) including platform (11), structure (55)

Lot distribution: 1124, 1127, 1131, 1133, 1134, 1149, 1150, 1152, 1161, 1166, 1167, 1175, and 1182 (Chichén Itzá); 1181 (Cumtun); 1203 (Isla Cerritos); 1047 (Uxmal); 1122 (Yula)

Regional distribution: Mayapan, Uxmal (Smith 1971), Isla Cerritos (Robles Castellanos 1988), San Gervasio (Peraza 1993), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971;

Winemiller 1997), Dzibilchaltún (Ochoa Rodriguez 1995),
Edzná (Boucher 2001), Becan (Ball 1977), Rio Bec (Rojas 1989)

Group: Red Mama

Type-Variety: Mama Red: Mama (117)

Mama Red: Cancun (5)

Mama Red: Not Specified (1)

Papacal Incised: Papacal (1)

Established by: (Smith 1971)

Frequency: 124 sherds

Vessel shape: Basin (3), bowl flat base (11), bowl flat base
tripod (1), bowl grater tripod (1), bowl round base (1), censer
(1), jar (106)

Function: Domestic, jars used for water or grain storage, and
bowls as food containers or serving vessels, basins, and grater
for food preparation. Might have functioned in ceremonial
contexts such as religious rites, burials as grave goods or
offerings, and dedicatory caches.

Water feature context: 54 sherds (43.55%) including *cenote*
(45), *chultun* (5), *haltun* (1), *rejollada* (3)

Other context: 70 sherds (56.45%) including house (5), platform
(8), structure (57)

Lot distribution: 1016, 1017, 1018, 1020, 1021, 1022, 1023,
1024, 1025, 1026, and 1027 (Mayapan); 1123 (Yula); 1065

(Sayil); 1181 (Cumtun); 1152, 1155, 1165, and 1182 (Chichén Itzá); 1230 (Xelha)

Regional distribution: Mayapan, Acanceh, Tecoh, Ucu, and Champoton (Smith 1971), Isla Cerritos (Robles Castellanos 1988), Cobá (Robles Castellanos 1990), El Vergel (Fernandez del Valle 1992), San Gervasio (Peraza Lope 1993), Aké (Quintal Suaste 1993), Playa del Carmen (Perez Rivas 1993), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971; Winemiller 1997), Toh cave (Rissolo 2001), Ciudad del Carmen (Ball 1978), Hochob (Carrasco and Boucher 1985), Edzná (Boucher 2001)

Group: Red Payil

Type-Variety: Payil Red: Payil (4)

Palmul Incised: Palmul (2)

Established by: (Smith 1971)

Frequency: 6 sherds

Vessel shape: Bowl flat base (2), jar (4)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 3 sherds (50%) including *cenote* (2), *chultun* (1)

Other context: 3 sherds (50%) including activity area (1), structure (2)

Lot distribution: 1162 (Chichén Itzá); 1200 (Coba); 1024 and 1026 (Mayapan), 1122 (Yula)

Regional distribution: Yucatán West Coast and Coba (Robles Castellanos 1990), Yucatán East Coast particularly at Tulum and Ichpaatun (Sanders 1960); Mayapan (Smith 1971)

Group: Red Sacpokana

Type-Variety: Sacpokana Red: Sacpokana

Established by: Smith 1971 (Smith 1971)

Frequency: 1 sherd

Vessel shape: jar parenthesis rim (1)

Function: Domestic, used for water transport, capture, storage, and household tasks such as washing articles or bathing.

Water feature context: 1 sherd (100%) including cave (1)

Other context: None

Lot distribution: 1216 (Acanceh)

Regional distribution: Dzibilchaltún, Mani Cenote, and Mayapan (Smith 1971)

Group: Red Teabo

Type-Variety: Teabo Red: Teabo

Established by: (Smith 1971)

Frequency: 76 sherds

Vessel shape: Bowl flat base (54), bowl grater tripod (1), bowl round bottom (1), jar (20)

Function: Domestic, jars used for water or grain storage, bowls as food containers or serving vessels, and grater for food preparation. Might have functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 24 sherds (31.58%) including cenote (1), *chultun* (13), well (6), *rejollada* (4)

Other context: 52 sherds (68.42%) including path (1), platform (2), *sacbe* (2), structure (44), tower (3)

Lot distribution: 1221 (Acanmul); 1184 (*Akalchen*), 1015 (Aké), 1128, 1152, 1155, 1161, 1161, 1169, 1171, 1172, 1173, 1174 and 1175 (Chichén Itzá), 1199 (Coba), 1110, 1111, 1118 and 1119 (Dzibilchaltún), 1204 (Edzná), 1024 (Mayapan), 1055 and 1060 (Nohpat), 1079, 1085, 1087, 1089 and 1091 (*Sacbe Uxmal-Nohpat*), 1076 (Sayil), 1042 and 1052 (Uxmal), 1122 (Yula)

Regional distribution: Acanceh, Chacchob, Dzan, Hunacti, Kabah, Labná, Mayapan, Colonia Miraflores, Mulchic, Oxxintok, Oxxutzcab, Sabacché, Sayil, Tecoh (Smith 1971), El Meco (Andrews and Robles Castellanos 1986), Komchen (Andrews V 1988), Isla Cerritos (Robles Castellanos 1988), Uxmal (Maldonado Cardenas, Kurjack and Green Robertson 1989), Cobá (Robles Castellanos 1990), Xelha (Canche Manzanero 1992), El

Vergel (Fernandez del Valle 1992), San Gervasio (Peraza Lope 1993), Aké (Quintal Suaste 1993), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971), Maas cave (Rissolo 2001), Becan (Ball 1977)

Group: Red Tipikal

Type-Variety: Unto Black-on-Striated: Unto (1)

Tipikal Red-on-Striated: Tipikal (1)

Established by: (Smith 1971)

Frequency: 2 sherds

Vessel shape: Jar (2)

Function: Domestic, used for water transport, capture, storage, and household tasks such as washing articles or bathing.

Water feature context: 1 sherd (50%), including cenote (1)

Other context: 1 sherd (50%) including structure (1)

Lot distribution: 1215 (Acanceh); 1221 (Acanmul)

Regional distribution: Mayapan, Holactun y Mani (Smith 1971), Komchen (Andrews V 1988), El Vergel (Fernandez del Valle 1992), Aké (Quintal Suaste 1993), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971), Toh and Pech caves (Rissolo 2001)

Group: Red Xanaba

Type-Variety: Xanaba Red: Xanaba

Established by: Smith 1971:31 (Smith 1971)

Frequency: 5 sherds

Vessel shape: Jar (3), bowl round ringstand base (1), bowl flat base (1)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 2 sherds (40 %) including cenote (1), *rejollada* (1)

Other context: 3 sherds (60%) including sacbe (1), architectural group (2)

Lot distribution: 1002 and 1009 (Aké); 1156 (Chichén Itzá); 1196 (Coba)

Regional distribution: Acanceh, Mayapan y Yaxuna (Smith 1971), Komchen (Andrews V 1988), Isla Cerritos (Robles Castellanos 1988), Cobá (Robles Castellanos 1990), Xelha (Canche Manzanero 1992), El Vergel (Fernandez del Valle 1992), Aké (Quintal Suaste 1993), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971), Toh and Pech caves (Rissolo 2001)

Group: Saxche

Type-Variety: Saxche Orange Polychrome: Not Identified

Established by: (Smith and Gifford 1966)

Frequency: 17 sherds

Vessel shape: Bowl rounded sides flat bottom (7), dishes outsloping sides flat bottom (10)

Function: Tradeware, possibly used for elite consumption. Bowls and dishes used for domestic purposes as food containers or for serving vessels. Might have functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 15 sherds (88.23%) including well (1), *aguada* (13), cistern (1)

Other context: 2 sherds (11.77%) including structure (1), path (1)

Lot distribution: 1006 (Aké), 1199 (Coba), 1238 (Dzibanché), 1190 (Noh Aktun), 1226 (Noh Ichmul)

Regional distribution: Kabah, Mayapan (Smith 1971), Becan (Ball 1977), Isla Cerritos (Robles Castellanos 1988), Cobá (Robles Castellanos 1990), Toh and Pak Chen caves (Rissolo 2001)

Group: Say Early Slate

Type-Variety: Chemax Black-on-Slate: Chemax

Established by: Robles 1990: 108-109 (Robles Castellanos 1990)

Frequency: 1 sherd

Vessel shape: Jar oval shape body large neck flat base (1)

Function: Domestic, jars for water or grain storage.

Water feature context: 1 (100%) including *chultun* (1)

Other context: None

Lot distribution: 1042 (Uxmal)

Regional distribution: Coba and Yaxuna (Robles Castellanos 1990), Dzibilchaltún (Simmons 1973, 1979), Chichén Itzá (Perez de Heredia Puente 1999), Tacbi Ha cave (Rissolo 2001)

Group: Sierra

Type-Variety: Sierra Red: Sierra (9)

Sierra Red: Chon (1)

Sierra Red: Light slip (6)

Sierra Red: Not identified (2)

Repasto Black-on-red: Repasto (2)

Ciego Composite: Ciego (1)

Established by: (Smith 1971)

Frequency: 21

Vessel shape: Bowl flat base (16), jar (4), bowl flaring side (1)

Function: Domestic, bowls as food containers or for serving vessels. In some instances, bowls functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 12 sherds (57.14%), including *aguada* (2), cave (4), *cenote* (2), *chultun* (4)

Other context: 9 sherds (42.86%), including architectural group (1), structure (8)

Lot distribution: 1002 and 1015 (Aké); 1042 (Uxmal); 1196

(Coba); 1204 (Edzná); 1215 and 1216 (Acanceh); 1223 and 1224
(Calakmul); 1230 (Xelha); 1238 (Dzibanché)

Regional distribution: Mayapan (Smith 1971), Becan (Ball 1977),
Komchen (Andrews V 1988), Xelha (Canche Manzanero 1992), El
Vergel (Fernandez del Valle 1992), San Gervasio (Peraza Lope
1993), Aké (Quintal Suaste 1993), Playa del Carmen (Perez Rivas
1993), Chichén Itzá (Perez de Heredia Puente 1999), Toh, Pech,
Maas, Pakchen, and Tam Ha caves (Rissolo 2001)

Group: Slate Dzitas

Type-Variety: Dzitas Slate: Dzitas (676)

Balam Canche Red-on-Slate: Balam Canche (4)

Balantun Black-on-Slate: Balantun (116)

Chacmay Incised: Chacmay (4)

Timak Composite: Timak (4)

Established by: (Smith 1971)

Frequency: 805 sherds

Vessel shape: Basin (116), bowl flat base (65), bowl flat base
tripod (4), grater tripod (26), bowl round base (2),
bowl round ringstand base (18), jar (570), jar tripod (1), jug
(1), not determined (2)

Function: Domestic, jars and jug for water or grain storage, bowls, basins, and graters as food containers or serving vessels, and basins for food preparation.

Water feature context: 284 sherds (35.28%), including cenote (6), *chultun* (185), well (30), *rejollada* (63)

Other context: 521 sherds (64.72%), including activity area (1), path (1), platform (198), *sacbe* (1), structure (320)

Lot distribution: 1184 (*Akalchen*); 1002 (*Aké*); 1124, 1125, 1127, 1128, 1129, 1130, 1131, 1133, 1134, 1149, 1150, 1152, 1155, 1156, 1157, 1158, 1159, 1161, 1162, 1163, 1165, 1166, 1167, 1168, 1169, 1171, 1172, 1175, 1177, 1178, 1179, and 1182 (*Chichén Itzá*); 1199 and 1200 (*Coba*); 1181 (*Cumtun*); 1203 (*Isla Cerritos*); 1058 (*Nohpat*); 1089 (*Sacbe Uxmal-Nohpat*); 1042 and 1048 (*Uxmal*); 1122 (*Yula*)

Regional distribution: *Chichén Itzá* (Perez de Heredia Puente 1999; Smith 1971; Winemiller 1997), *El Cuyo Sur* at *Rio Lagartos*, *Isla Huaymil* (Ball 1978), *El Meco* (Andrews and Robles Castellanos 1986), *Isla Cerritos* (Robles Castellanos 1988), *Cobá* (Robles Castellanos 1990), *Xelha* (Canche Manzanero 1992), *El Vergel* (Fernandez del Valle 1992), *San Gervasio* (Peraza Lope 1993), *Aké* (Quintal Suaste 1993), *Playa del Carmen* (Perez Rivas 1993), *Dzibilchaltún* (Ochoa Rodriguez 1995), *Hochob* (Carrasco and Boucher 1985), *Becan* (Ball 1977), *Rio Bec* (Rojas 1989), *Edzná* (Boucher 2001)

Group: Slate Muna

Type-Variety: Muna Slate: Muna (798)

Muna Slate: Brown Slip (41)

Muna Slate: Tabi (1)

Muna Slate: Not Identified (2)

Akil Impressed: Akil (3)

Chumayel Red-on-Slate: Chumayel (3)

Sacalum Black-on-Slate: Sacalum (37)

Tekit Incised: Tekit (3)

Established by: (Smith 1971)

Frequency: 888 sherds

Vessel shape: Basin (203), bowl flat base (104), bowl flat base tripod (16), grater tripod (12), bowl round base (10), bowl round ringstand base (6), *chultun* jar (8), jar (519), jar inverted Z lip (3), miniature bowl round base (1), vase (1), not determined (1)

Function: Domestic, jars used for water transport, capture, storage, and household tasks such as washing articles or bathing. *Chultun* jars were used for water collection. , basins and graters for food preparation, bowls and vases as food container or for serving vessels. Miniature bowls and standard bowls could have functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: 557 sherds (62.72%) including *aguada* (54), *akalchen* (14), cave (3), *cenote* (26), *chultun* (366), cistern (6), *haltun* (4), well (63), *rejollada* (19), *sartenejas* (2)

Other context: 331 sherds (37.28%) including activity area (1), altar (1), architectural group (11), platform (57), *sacbe* (19), structure (229), terrace (2), tower (11)

Lot distribution: 1215 and 126 (Acanceh); 1220 and 1221 (Acanmul); 1185 (*Akalchen*); 1002, 1003, 1004, 1006, 1107, 1009, 1013, 1014, and 1015 (*Aké*); 1124, 1128, 1130, 1133, 1134, 1155, 1161, 1162, 1169, 1171, 1173, 1174, 1175, 1176, 1177, 1180, and 1182 (*Chichén Itzá*); 1187, 1188, 1193, 1196, 1200, 1217, and 1218 (*Coba*); 1190 (*Noh Aktun*); 1181 (*Cumtun*); 1235 (*Dzib Chaac*); 1098, 1104, 1105, 1107, 1110, 1111, 1112, 1116, 1117, 1118, 1119, 1120, and 1121 (*Dzibilchaltún*); 1204 (*Edzná*); 1203 (*Isla Cerritos*); 1017, 1018, 1020, 1021, and 1024 (*Mayapan*); 1227 (*Noh Ichmul*); 1055, 1056, 1057, 1058, 1059, 1060, and 1061 (*Nohpat*); 1079, 1080, 1082, 1084, 1085, 1086, 1087, 1091, 1092, and 1093 (*Sacbe Uxmal-Nohpat*); 1062, 1063, 1064, 1065, 1066, 1067, 1068, 1069, 1071, 1074, 1075, and 1076 (*Sayil*); 1031, 1032, 1035, 1036, 1037, 1038, 1039, 1040, 1041, 1042, 1044, 1046, 1048, 1050, and 1051 (*Uxmal*); 1229 and 1230 (*Xelha*); 1122 and 1123 (*Yula*)

Regional distribution: Brown slip variety has been reported at Chichén Itzá, Mayapan, Ucú (Smith 1971), Becan (Ball 1977), El Meco (Andrews and Robles Castellanos 1986), Isla Cerritos (Robles Castellanos 1988), Uxmal (Maldonado Cardenas, Kurjack and Green Robertson 1989), Cobá (Robles Castellanos 1990), Xelha (Canche Manzanero 1992), El Vergel (Fernandez del Valle 1992), San Gervasio (Peraza Lope 1993), Aké (Quintal Suaste 1993), Playa del Carmen (Perez Rivas 1993). Muna Variety has been reported at Dzibilchaltún (Ochoa Rodriguez 1995; Smith 1971), Aké, Chacchob, Chichén Itzá, Dzibiac, Hunacti, Kabah, Labna, Mayapan, Miraflores, Mulchic, Oxkutzcab, Sayil, Sobonke, Tecoh, Tihoo, Ucú, Uxmal, Xcanatun, Xulmil, Yaxuna, *Aguada Gande*, Coba, Cozumel, Ichmul, Tancah, Vista Alegre, Xcaret, Xelha, Canbalam, Cayal, Dzibilnocac, Huaymil, Jaina, Queja, Santa Rosa Xtampak, Tohkok, and Xpuhil (Smith 1971), Chichén Itzá (Perez de Heredia Puente 1999; Winemiller 1997), Edzná (Boucher 2001; Forsyth 1983; Smith 1971)

Group: Tancachacal

Type-Variety: Tancachacal Slate: Tancachacal

Established by: (Ball 1977)

Frequency: 1 sherd

Vessel shape: Bowl flat base (1)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: None

Other context: 1 sherd (100%) including platform (1)

Lot distribution: 1213 (Edzná)

Regional distribution: Becan and Rio Bec area (Ball 1977)

Group: Thin-Slate Ticul

Type-Variety: Ticul Thin- Slate: Ticul (29)

Ticul Thin Slate: Xelha (3)

Ticul Thin Slate: Not Identified (1)

Zumpulche Thin Slate: Zumpulche (2)

Tabi Gouged-Incised: Tabi (1)

Xul Incised: Xul (5)

Established by: (Smith 1971)

Frequency: 41 sherds

Vessel shape: Bowl flat base (36), bowl flat base tripod (1), cylindrical vase (1), jar (1), miniature jar (1), vase (1)

Function: Domestic, jars for water or grain storage, bowls as food containers or serving vessels, and basins for food preparation. In some instances ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches. This would specifically apply to cylindrical vases, and miniature jars that functioned as religious

paraphernalia and were occasionally included in burial offerings.

Water feature context: 29 sherds (70.73%), including *aguada* (6), *cenote* (1), *chultun* (16), cistern (3), well (3)

Other context: 12 sherds (29.27%), including activity area (1), path (1), platform (1), *sacbe* (1), structure (5), tower (3)

Lot distribution: 1006, 1013, and 1015 (Aké); 1149 and 177 (Chichén Itzá); 1199 and 1200 (Coba); 1181 (Cumtun); 1105 and 1121 (Dzibilchaltún); 1204 and 1205 (Edzná); 1017 (Mayapan); 1057, 1058, and 1061 (Nohpat); 1091 and 1092 (*Sacbe Uxmal-Nohpat*); 1065 (Sayil); 1031, 1038, 1039, 1046 (Uxmal); 1122 (Yula)

Regional distribution: Acanceh, Aké, Chanpuuc, Dzebtun, Dzibilchaltún, Kabah, Labna, Mani, Mayapan, Miraflores, Oxkintok, Sayil, Uxmal, Yaxuna, *Aguada Grande*, Calderitas, San Miguel Cozumel, Tancah, and Hochob (Smith 1971), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971; Winemiller 1997). *Xelha* variety has been reported at El Meco (Andrews and Robles Castellanos 1986), Cobá (Robles Castellanos 1990), El Vergel (Fernandez del Valle 1992), Aké (Quintal Suaste 1993), Playa del Carmen (Perez Rivas 1993), and Dzibilchaltún (Ochoa Rodriguez 1995)

Group: Tienda

Type-Variety: Chencoyi Black-on-Thin Slate: Chencoyi

Established by: (Forsyth 1983)

Frequency: 2 sherds

Vessel shape: Bowl flat base (1), vase (11)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 2 sherds (100) including *aguada* (1), *chultun* (1)

Other context: None

Lot distribution: 1238 and 1239 (Dzibanché)

Regional distribution: Edzná (Forsyth 1983), Becan (Ball 1977), Oxpelchen and Cakamaax (Williams Beck 1999)

Group: Timucuy

Type-Variety: Tituc Orange-Polychrome: Not Identified

Established by: (Smith 1971)

Frequency: 1 sherd

Vessel shape: Bowl basal flange flat base (1)

Function: Tradeware, possibly used for elite consumption. Might have functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches.

Water feature context: None

Other context: 1 sherd (100%) including path (1)

Lot distribution: 1199 (Coba)

Regional distribution: Oxkintok, Mayapan, Acanceh, Cenote Mani, Kabah, and Yaxuna (Brainerd 1958), Coba and Tancah (Robles Castellanos 1990), Acanceh, Balam Canche cave, Kabah, Labna, Mani, Mayapan, Oxkintok, Sayil, Yaxuna (Smith 1971), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971), Toh and Tabi Ha caves (Rissolo 2001)

Group: Tinaja

Type-Variety: Tinaja Red: Tinaja (8)

Tinaja Red: NE Impressed (2)

Established by: (Smith and Gifford 1966)

Frequency: 10 sherds

Vessel shape: Jar (1), bowl flat base (9)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 10 sherds (100 %) including *cañada* or canal (1), *chultun* (9)

Other context: None

Lot distribution: 1206 (Edzná); 1239 (Dzibanché); 1240

(Kohunlich)

Regional distribution: Becan (Ball 1977), Chichén Itzá (Perez de Heredia Puente 1999)

Group: Triunfo

Type-Variety: Triunfo Striated: Triunfo (26)

Triunfo Striated: Not Identified (3)

Established by: (Ball 1977)

Frequency: 29 sherds

Vessel shape: Jar wide-mouth high neck and round bottom (29)

Function: Domestic, used for water transport, capture, storage, and household tasks such as washing articles or bathing.

Water feature context: 28 sherds (96.55%) including *aguada* (17), *chultun* (11)

Other context: 1 sherd (3.45%) including platform (1)

Lot distribution: 1152 and 1182 (Chichén Itzá), 1238 (Dzibanché), 1204 (Edzná), 1241 (Kohunlich), 1057 (Nohpat), 1081 (Sacbe Uxmal-Nohpat), 1045 (Uxmal)

Regional distribution: Becan (Ball 1977)

Group: Unslipped Achiote

Type-Variety: Saban Unslipped: Saban (20)

Saban Unslipped: Becoob (6)

Saban Unslipped: Not Identified (20)

Chancenote Striated: Chancenote (3)

Tancah Unslipped: Tancah (2)

Established by: (Smith 1971)

Frequency: 51 sherds

Vessel shape: Bowl flat base (5), bowl round ringstand base (6), jar (40)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 15 sherds (29.41%) including *aguada* (2), *chultun* (3), well (10),

Other context: 36 sherds (70.59%) including architectural group (2), platform (7), sacbe (5), structure (20), terrace (1)

Lot distribution: 1221 (Acanmul); 1004 and 1014 (Aké); 1186, 1196, 1231, and 1236 (Coba); 1190 (Noh Aktun); 1238 (Dzibanché); 1098 and 1118 (Dzibilchaltún); 1125 (Noh Ichmul); 1080, 1081, 1084, 1085, 1086, 1087, 1092 (Sacbe Uxmal-Nohpat); 1230 (Xelha); 1122 (Yula)

Regional distribution: Mayapan and Oxkintok (Smith 1971), Becan (Ball 1977), Komchen (Andrews V 1988), Isla Cerritos (Robles Castellanos 1988), Cobá (Robles Castellanos 1990), Xelha (Canche Manzanero 1992), El Vergel (Fernandez del Valle 1992), San Gervasio (Peraza Lope 1993), Aké (Quintal Suaste 1993), Playa del Carmen (Perez Rivas 1993), Chichén Itzá (Perez de Heredia Puente 1999; Smith 1971); Toh, Pech, Pac Chen, and Tam Ha caves (Rissolo 2001)

Group: Unslipped Chum

Type-Variety: Chum Unslipped: Chum (97)

Chum Unslipped: Not Identified (4)

Halacho Impressed: Halacho (1)

Yokat Striated: Yokat (305)

Established by: (Smith 1971)

Frequency: 407 sherds

Vessel shape: Bowl flat base (1), bowl round ringstand base (1), jar (405)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels. Decorated variety functioned in ceremonial contexts such as religious rites, burials as grave goods or offerings, and dedicatory caches

Water feature context: 257 sherds (63.15%) including *aguada* (1), cave (4), *cenote* (16), *chultun* (194), *haltun* (4), well (38)

Other context: 150 sherds (36.85 %) including altar (1), mound (1), platform (50), *sacbe* (25), structure (53), tower (20)

Lot distribution: 1215 and 1216 (Acanceh); 1220 and 1221 (Acanmul); 1003, 1004, 1007, 1009, 1011, 1013, 1014, and 1015 (Aké); 1124, 1149, 1152, 1161, 1162, and 1171 (Chichén Itzá); 1181 (Cumtun); 1235 (Dzib Chaac); 1098, 1104, 1105, 1107, 1110, 1111, 1112, 1115, 1116, 1118, 1119, 1120, and 1121 (Dzibilchaltún); 1203 (Isla Cerritos); 1017, 1020, 1021, 1024,

1025 (Mayapan); 1226 and 1227 (Noh Ichmul); 1055, 1057, 1058, 1059, and 1061 (Nohpat); 1078, 1079, 1080, 1081, 1087, 1089, 1091, and 1092 (Sacbe Uxmal-Nohpat); 1062, 1063, 1064, 1065, 1066, 1067, 1068, 1069, 1071, 1074, 1075, and 1076 (Sayil); 1042, 1043, 1044, 1045, 1046, 1048, 1050, 1051, and 1052 (Uxmal); 1122 (Yula)

Regional distribution: Komchen (Andrews V 1988), Isla Cerritos (Robles Castellanos 1988), Uxmal (Maldonado Cardenas, Kurjack and Green Robertson 1989), El Vergel (Fernandez del Valle 1992), Aké (Quintal Suaste 1993), Dzibilchaltún (Ochoa Rodriguez 1995), Chichén Itzá (Perez de Heredia Puente 1999; Winemiller 1997)

Group: Unslipped Navula-Panaba

Type-Variety: Chen Mul: Modeled: Chen Mul (6)

Huhi Impressed: Huhi (3)

Navula Unslipped: Navula (7)

Navula Unslipped: Not identified (7)

Yacman Striated: Yacman (21)

Cehac-Hunacti Composite: Cehac (1)

Cehac Painted: Cehac (2)

Established by: (Smith 1971)

Frequency: 48 sherds

Vessel shape: Bowl flat base (1), jar (34), ladle (2), censer (8), dish (1),

Function: Domestic, jars for water or grain storage, bowls and dishes as food containers or serving vessels. Ladles and censers functioned as ceremonial items in religious rites, as grave goods or offerings, and were placed in dedicatory caches.

Water feature context: 19 sherds (39.58%) including *cenote* (15), well (1), cave (1), *rejollada* (2)

Other context: 29 sherds (60.42%) including platform (12), structure (8), house (8), path (1)

Lot distribution: 1214 (Acanceh); 1002 (Aké); 1152, 1161, and 1169 (Chichén Itzá); 1197 and 1219 (Coba); 1190 (Noh Aktun); 1213 (Edzná); 1017, 1018, 1022, 1024, 1026, 1027 (Mayapan); 1230 (Xelha); 1122 (Yula)

Regional distribution: Mayapan (Smith 1971), Chichén Itzá (Brainerd 1958; Perez de Heredia Puente 1999; Smith 1971; Winemiller 1997), Becan (Ball 1977), El Meco (Andrews and Robles Castellanos 1986), Cobá (Robles Castellanos 1990), Isla Cerritos (Robles Castellanos 1988), Komchen (Andrews V 1988), Xelha (Canche Manzanero 1992), San Gervasio (Peraza Lope 1993), Aké (Quintal Suaste 1993), Playa del Carmen (Perez Rivas 1993) Chankon (Brainerd 1958), Dzibilchaltún (Ochoa Rodriguez 1995; Simmons 1973, 1979; Smith 1971), Emal, Yaxcopoil, Becan, Isla Cilvituk and Sakik (Ball 1977), Atasta and Champoton (Ruz

Lhullier 1969), *Aguada Grande*, *Calderitas*, *Ichpaatun*, *Chetumal Bay*, *Chiquilá*, *Cozumel*, *Isla Mujeres*, *Tancah* and *Tulum* (Sanders 1960), *Maas cave* (Rissolo 2001)

Group: Unslipped Sisal

Type-Variety: Sisal Unslipped: Sisal (15)

Sisal Unslipped: Not Identified (1)

Piste Striated: Piste (238)

Established by: (Smith 1971)

Frequency: 254 sherds

Vessel shape: Bowl flat base (4), dish (1), jar (249)

Function: Domestic, jars for water or grain storage and bowls and dishes as food containers or serving vessels. In ceremonial contexts these forms functioned as grave goods or offerings, and dedicatory caches.

Water feature context: 134 sherds (52.76%) including *aguada* (1), *akalchen* (12), *cenote* (2), *chultun* (87), *haltun* (2), well (20), *rejollada* (10)

Other context: 120 sherds (47.24%) including path (1), platform (23), *sacbe* (1), structure (92), tower (3)

Lot distribution: 1221 (Acanmul); 1128, 1129, 1130, 1134, 1150, 1152, 1156, 1161, 1162, 1166, 1167, 1173, 1175, 1177, 1178, 1179, 1182 (Chichén Itzá); 1188 (Coba); 1190 (Noh Aktun); 1181 (Cumtun); 1102, 1111, 1114, 1116, 1117, 1118, 1121

(Dzibilchaltún); 1203 (Isla Cerritos); 1018, 1020, 1024
(Mayapan); 1059 (Nohpat); 1079, 1080, and 1085 (Sacbe Uxmal-
Nohpat); 1063, 1064, and 1065 (Sayil); 1122 (Yula)

Regional distribution: Becan (Ball 1977), Isla Cerritos (Robles
Castellanos 1988), Chichén Itzá (Perez de Heredia Puente 1999;
Winemiller 1997), Dzibilchaltún (Ochoa Rodriguez 1995)

Group: Unslipped Yuncu

Type-Variety: Yuncu Unslipped: Yuncu

Established by: (Smith 1971)

Frequency: 1 sherd

Vessel shape: jug (1)

Function: Domestic, jug for water or grain storage and service.

Water feature context: 1 sherd (100%) including *cañada* or canal
(1)

Other context: None

Lot distribution: 1240 (Kohunlich)

Regional distribution: Mani and Mayapan (Smith 1971)

Group: Unspecified

Type-Variety: Dos Caras Striated: Dos Caras

Established by: (Robles Castellanos 1990)

Frequency: 12 sherds

Vessel shape: Bowl flat base (1), jar (11)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: None

Other context: 12 sherds (100%) including path (12)

Lot distribution: 1199 (Coba)

Regional distribution: Coba (Robles Castellanos 1990)

Group: Unspecified

Type-Variety: Dzibical Black-on-Orange: Dzibical

Established by: (Simmons 1973, 1979)

Frequency: 1 sherd

Vessel shape: Jar (1)

Function: Domestic (jar for water or grain storage)

Water feature context: 1 (100%) including *akalchen* (1)

Other context: None

Lot distribution: 1185 (*Akalchen*)

Regional distribution: Coba (Robles Castellanos 1990),

Dzibilchaltún (Simmons 1973, 1979)

Group: Unspecified

Type-Variety: Shangurro Red-on-Orange: Shangurro (2)

Shangurro Red-on-Orange: Not Identified (1)

Established by: not available

Frequency: 3 sherds

Vessel shape: jar (2), bowl flat base (1)

Function: Domestic, jars for water or grain storage and bowls as food containers or serving vessels.

Water feature context: 2 sherds (66.66%) including *cenote* (2)

Other context: 1 sherd (33.33%) including *sacbe* (1)

Lot distribution: 1009 (Aké); 1215 (Acanceh)

Regional distribution: Toh cave (Rissolo 2001)

Group: Unspecified

Type-Variety: Tinum Red-on-Cinnamon: Tinum

Established by: (Smith 1971)

Frequency: 2 sherds

Vessel shape: Ladle-handle censer flat base (2)

Function: Used in ceremonial contexts for ritual activities.

Water feature context: None

Other context: 2 sherds (100%) including structure (2)

Lot distribution: 1122 (Yula)

Regional distribution: Chichén Itzá (Perez de Heredia Puente 1999), Mayapan (Smith 1971)

Group: Vista Alegre

Type-Variety: Vista Alegre Striated: Vista Alegre

Established by: (Sanders 1960)

Frequency: 17 sherds

Vessel shape: Bowl round sides ringstand base (17)

Function: Domestic, bowls as food containers or for serving vessels.

Water feature context: 7 sherds (41.17%) including *aguada* (3), *chultun* (1), well (3)

Other context: 10 sherds (58.83%) including architectural group (1), sacbe (1), structure (8)

Lot distribution: 1009 (Aké), 1176 (Chichén Itzá), 1188 and 1196 (Coba), 1190 (Noh Aktun), 1203 (Isla Cerritos), 1230 (Xelha)

Regional distribution: Canbalam, Coba (Robles Castellanos 1990), Isla Cerritos, Emal, El Cuyo South at Rio Lagartos (Ball 1978), Chiquilá, Vista Alegre, Tancah, San Miguel, *Aguada Grande*, Cozumel, Monte Bravo, El Diez, Santa Maria, Kilómetro 14 (Sanders 1960), El Meco (Andrews and Robles Castellanos 1986), Toh and Tacbi Ha caves (Rissolo 2001)

APPENDIX C

ARTIFACTS AND ECOFACTS

Clay Artifacts

Category: Net weight

Total: 3

Catalog numbers: 1153-13-03, 1203-13-03, and 1203-13-04

Description: Net weights are semi-rectangular, reshaped ceramic sherds, with polished sides, most likely evidence of use wear, and notched on two opposite edges. The small size of these weights suggests they were used in slow moving water.

Function: For Phillips (1979), net weights were used in fishing activities.

Water feature context: None

Other context: Structure (2)

Lot distribution: 1153 (Chichén Itzá); 1203 (Isla Cerritos)

Category: Polisher or Disk-shaped decorative element

Total: 1

Catalog number: 1239-13-02

Description: Disk-shaped with a thumb-size depression on one side and a flat well polished surface on the other suggestion the artifact functioned as a polisher. Could be the result of reusing a striated pottery fragment. Alternatively, this object

might be a decorative element from a ceramic vessel such as a censer.

Function: (Ochoa Rodriguez 1995) reports that polishers were used to finish the surface of vessels before firing.

Water feature context: *Chultun* (1)

Other context: None

Lot distribution: 1239 (Dzibanché)

Category: Rattle ball

Total: 6

Catalog numbers: 1122-13-05, 1122-13-06, 1122-13-07, 1122-13-08, 1122-13-09, and 1122-13-10

Description: Spherical piece fired clay with three drilled holes. Several contain burn marks, most likely from milpa fires.

Function: Part of hollow vessel supports.

Water feature context: None

Other context: Structure (6)

Lot distribution: 1122 (Yula)

Category: Anthropomorphic figurine

Total: 1

Catalog number: 1196-13-05

Description: Possible censer fragment shaped in the form of a human head. Figure is wearing a headdress and ear-spools.

Function: Censers were part of religious paraphernalia or sub-assemblages and represent ceremonial behavior.

Water feature context: None

Other context: Architectural group (1)

Lot distribution: 1196 (Coba)

Category: Tejo

Total: 1

Catalog number: 1063-13-02

Description: Reused sherds of irregular, oval, or rectangular shape. Tejos are polished on their sides and may or may not have one or more perforations.

Function: Undetermined

Water feature context: *Chultun* (1)

Other context: None

Lot distribution: 1063 (Sayil)

Glass and Metal

Category: Fragment

Total: 8

Catalog numbers: 1153-07-01, 1162-7-01, 1162-07-02, 1119-07-01, 1225-07-02 to 05

Description: Includes a modern bottle, mirror, and possible dish fragments.

Function: Intrusive material resulting from modern activity.

Water feature context: *Chultun* (2), Well (1), *Rejollada* (2)

Other context: Structure (3)

Lot distribution: 1153 and 1162 (Chichén Itzá); 1119 (Dzibilchaltún); 1225 (Noh Ichmul)

Category: Coin

Total: 3

Catalog numbers: 122-08-01, 1186-08-01, 1190-08-03

Description: One Cent Mexico also known as a "*Josefita*" (Copper), Unidentified metal fragment (Copper), 1983 Fifty Cent piece, Mexico (Nickel)

Function: Intrusive material resulting from modern activity.

Water feature context: *Aguada* (1), well (1)

Other context: Structure (1)

Lot distribution: 1122 (Acanmul), 1186 (Coba), 1190 (Noh Aktun)

Category: Miscellaneous

Total: 3

Catalog numbers: 1001-08-01, 1092-08-01, 1161-08-01

Description: Section of a coa (sickle) blade (iron), complete rusted nail (steel), melted bullet (lead).

Function: Intrusive material resulting from modern activity.

Water feature context: Cenote (1)

Other context: Sacbe (1), platform (1)

Lot distribution: 1001 (Aké), 1092 (Sacbe Uxmal-Nohpat), 1161
(Chichén Itzá)

Groundstone, Stucco, and Quartz

Category: Quartz Fragment

Total: 3

Catalog numbers: 1185-14-01, 1190-14-02, 1241-14-01

Description: Quartz fragments with a semi-crystalline texture
were abundant in surface contexts particularly at Kohunlich.

Function: Not determined, possibly geofacts.

Water feature context: 3 including *akalchen* (1), well (1),
aguada (1)

Other context: None

Lot distribution: 1185 (*Akalchen*), 1190 (Noh Aktun), 1241
(Kohunlich)

Category: Geofact

Total: 16

Catalog numbers: 1111-04-02, 1112-04-02, 1200-04-08, 1152-04-
03, 1152-04-15, 1059-04-01

Description: Polished round or amorphous pieces of limestone most likely the result of weathering processes.

Function: None

Water feature context: Well (12), *chultun* (1)

Other context: Activity area (1), platform (2)

Lot distribution: 1111 and 1112 (Dzibilchaltún), 1200 (Coba), 1152 (Chichén Itzá), 1059 (Nohpat)

Category: Mano for both hands

Total: 4

Catalog numbers: 1238-04-01, 1239-04-03, 1239-04-04, 1153-04-02,

Description: Well polished cylindrical shape ground stone artifact that does not have flat sides.

Function: According to (Schlanger 1991), this type of mano was used to grind grains or minerals to be used as ceramic or clay tempers.

Water feature context: *Aguada* (1), *Chultun* (2), *Rejollada* (1)

Other context: None noted

Lot distribution: 1238 and 1239 (Dzibanché), 1153 (Chichén Itzá)

Category: Mano for single hand

Total: 4

Catalog numbers: 1023-04-05, 1065-04-01, 1065-04-02, 1164-04-01

Description: Well polished ovoid-shaped ground stone artifact with some flattening on the sides (see Jaeger 1988: 13-104) (Jaeger 1988).

Function: For (Schlanger 1991) this artifact was a type of mano that functioned as a grinder for pigments or food. Grinding to obtain a fine powder required short circular movements using the flat of the hand.

Water feature context: *Chultun* (2), *cenote* (1) *Rejollada* (1)

Other context:

Lot distribution: 1164 (Chichén Itzá), 1023 (Mayapan), 1065 (Sayil)

Category: Pestle (ground stone)

Total: 1

Catalog numbers: 1122-04-11

Description: Ground limestone pestle with elongated handle.

Function: Used with a mortar to finely-grind pigments or food.

Water feature context: None

Other context: Structure (1)

Lot distribution: 1122 (Yula)

Category: Flaked Disk

Total: 2

Catalog numbers: 1161-04-04, 1161-04-0

Description: Flaked limestone disk with two flat sides

Function: Unknown, possibly used as a vessel cover, hand-held scraper, carving, or cutting tool.

Water feature context: None

Other context: Platform (2)

Lot distribution: 1161 (Chichén Itzá)

Category: Sphere (Groundstone)

Total: 1

Catalog numbers: 1181-04-01

Description: Ground polished limestone sphere.

Function: Spherical objects like this artifact are typically defined as hammerstones (Andrews IV 1973; Winemiller 1996, 1997).

Water feature context: *Chultun* (1)

Other context: None

Lot distribution: 1181 (Chichén Itzá)

Category: Decorative architectural element

Total: 1

Catalog numbers: 1065-04-02

Description: Elongated cylindrical-shaped ground limestone decorative element.

Function: Possibly a portion of a decorative façade.

Water feature context: *Chultun* (1)

Other context: None

Lot distribution: 1065 (Sayil)

Category: Stucco fragment

Total: 83

Catalog numbers: 1220-11-01 to 07, 1008-11-01, 1128-11-01, 1129-11-02, 1130-11-01, 1151-11-01, 1178-11-01, 1110-11-01, 1115-11-03, 1116-11-01, 1118-11-02, 1119-11-02, 1205-11-02, 1206-11-02, 1208-11-02, 1203-11-06 and 07, 1021-11-01, 1059-11-03, 1060-11-01, 1082-11-02, 1063-11-01, 1067-11-01, 1069-11-01, 1070-11-01, 1071-11-01 and 02, 1071-11-01 and 02, 1074-11-01, 1045-11-01, 1047-11-01, 1049-11-01, 1053-11-01

Description: Plaster fragments, some containing traces of pigment (red and/or green). One sample is feather-shaped

Function: Lining for *chultun*, decorative elements, outer surface for structures.

Water feature context: *Chultun* (66), well (15), *cenote* (2),

Other context: Structure (3)

Lot distribution: 1220 (Acanmul); 1008 (Aké); 1128, 1129, 1130, 1151, and 1178 (Chichén Itzá); 1110, 1115, 1116, 1118, and 1119 (Dzibilchaltún); 1205, 1206, and 1208 (Edzná); 1203 (Isla Cerritos); 1021 (Mayapan); 1059 and 1060 (Nohpat); 1082 (Sacbe

Uxmal-Nohpat); 1063, 1067, 1069, 1070, 1071, 1072, and 1074
(Sayil); 1045, 1047, 1049, and 1053 (Uxmal)

Flaked Artifacts

Category: Flake (obsidian)

Total: 3

Catalog numbers: 1199-03-02, 1200-03-01, 1200-03-05

Description: Possible source is Ixtepeque; sample consists of
one black, one swirled gray, and one gray flake.

Function: Byproduct of blade production, unintentional fracture
or core preparation, flakes are irregularly shaped.

Water feature context: None

Other context: (3) path (1), activity area (2)

Lot distribution: 1199 and 1200 (Coba)

Category: Prismatic blade (obsidian)

Total: 28

Catalog numbers: 1221-03-01, 1224-03-01 and 1224-03-02, 1152-
03-01, 1161-03-01, 1196-03-01 to 04, 1197-03-01, 1199-03-01,
1200-03-02 to 04, 1200-03-06, 1231-03-01, 1232-03-01 and 02,
1190-03-01, 1239-03-01, 1112-03-01, 1207-03-02, 1203-03-01 and
02, 1016-03-01, 1122-03-01 to 03

Description: Source classification is preliminary. Collection
includes one complete prismatic blade (El Chayal), 2 distal

fragments (Pachuca and Ixtepeque), 13 proximal fragments (Ixtepeque and El Chayal), 12 medial fragments (El Chayal, Ixtepeque, and Michoacan). Eleven fragments were flaked from ground platform cores, three were retouched, and one is worn from either geo-turbation or use. Fifteen fragments are double and 13 are triple faceted.

Function: The ancient Maya used obsidian blades as multiple use cutting tools. The collection of blades found in a lakeside activity at Coba might have been used in fishing related activities

Water feature context: *Aguada* (2), *chultun* (4), well (2), *cenote* (1)

Other context: Structure (6), platform (2), architectural group (5), lakeside path (2), lakeside activity area (4)

Lot distribution: 1221 (Acanmul); 1224 (Calakmul); 1152 and 1161 (Chichén Itzá); 1196, 1197, 1999, 1200, 1231, and 1232 (Coba); 1190 (Noh Aktun); 1239 (Dzibanché); 1112 (Dzibilchaltún), 1207 (Edzná); 1203 (Isla Cerritos); 1016 (Mayapan), 1122 (Yula)

Category: Flaked blade (chert)

Total: 7

Catalog numbers: 1152-02-09, 1152-02-11 and 12, 1238-02-09, 1239-02-11, 1200-02-11, 1055-02-01

Description: Five complete blades and two fragments. Four are unifacial blades, one is a bifacial blade, and another has three facets. Two blades are burnt and one contains cortex.

Function: Blades were primarily used as cutting tools for a variety of materials including meat, plants, fabric or other soft materials.

Water feature context: *Aguada* (1), *chultun* (1)

Other context: Platform (3), activity area (1), structure (1)

Lot distribution: 1152 (Chichén Itzá); 1238 and 1239 (Dzibanché); 1200 (Coba); 1055 (Nohpat)

Category: Projectile point (chert)

Total: 3

Catalog numbers: 1022-02-01, 1239-02-15, 1152-02-10

Description: One complete point and distal fragment of a small triangular-shaped dart point, and one proximal fragment of a medium-sized triangular-shaped point.

Function: Component of hunting weapons

Water feature context: *Chultun* (1)

Other context: Structure (1), platform (1)

Lot distribution: 1022 (Mayapan); 1239 (Dzibanché); 1152 (Chichén Itzá)

Category: Chopper (chert)

Total: 1

Catalog numbers: 1122-02-04

Description: Fragment with evidence of retouching and reuse.

Function: Chopping or cutting.

Water feature context: None

Other context: Structure (1)

Lot distribution: 1122 (Yula)

Category: Unidentified bifacial point or blade (chert)

Total: 2

Catalog numbers: 1152-02-08, 1239-02-07

Description: Small fragments exhibiting retouch scars on two sides.

Function: Unknown

Water feature context: *Chultun* (1)

Other context: Platform (1)

Lot distribution: 1152 (Chichén Itzá); 1239 (Dzibanché)

Category: Flake (chert)

Total: 53

Catalog numbers: 1237-02-01 to 04, 1224-02-03 to 04, 1129-02-01, 1152-04 to 06, 1154-02-01 to 03, 1161-02-03, 1200-02-10, 1200-02-12 to 17, 1238-02-03 to 08, 1238-02-10 to 16, 1239-02-

08 to 10, 1239-02-12 to 14, 1207-02-01, 1213-02-03, 1241-02-02, 1022-02-02, 1023-02-01 to 04, 1027-02-01, 1225-02-01, 11061-02-01, 1091-02-01

Description: The byproduct of pressure-flaked lithic tool manufacture, unintentional fractures during production, or core preparation. Flakes are irregularly shaped, some appear to be retouched. Others include areas of cortex and a few contain three facets

Function: Size, shape, and quantity suggest that many of these flakes resulted from occasional retouch or fracture in manufacture or restoration of cutting surfaces. Flakes derive from chert tools, such as blades, points, and adze axes.

Water feature context: *Chultun* (13), *aguada* (10), *cenote* (1), *Rejollada* (10)

Other context: platform (8), activity area (7), structure (2), house (1), tower (1)

Lot distribution: 1237 (Becan); 1224 (Calakmul); 1129, 1161, 1152 and 1154 (Chichén Itzá); 1200 (Coba); 1238 and 1239 (Dzibanché); 1207 and 1213 (Edzná); 1241 (Kohunlich); 1022, 1023, and 1027 (Mayapan); 1225 (Noh Ichmul); 1061 (Nohpat); 1091 (Sacbe Uxmal-Nohpat)

Category: Core (chert)

Total: 9

Catalog numbers: 1201-02-01, 1152-02-02, 1200-02-18, 1238-02-02, 1239-02-05 and 06, 1213-02-01 and 02, 1088-02-02

Description: Large and medium-sized core fragments. Some surfaces include cortex.

Function: Raw material used to manufacture blades, points, and tools

Water feature context: *Aguada* (1), *chultun* (2)

Other context: Activity area (1), platform (3), Road (2)

Lot distribution: 1201 (*Akalchen*); 1152 (Chichén Itzá); 1200 (Coba); 1238 and 1239 (Dzibanché); 1213 (Edzná); 1088 (Sacbe Uxmal-Nohpat)

Ecofacts: Coral and Mollusca

Category: Fragment (Coral)

Total: 11

Catalog numbers: 1020-12-01, 1027-12-02, 1125-12-01, 1230-12-11

Description: Fossilized coral fragments

Function: Undetermined, might be ceremonial or geofacts

Water feature context: *Haltun* (1), *chultun* (5)

Other context: House (4), structure (1)

Lot distribution: 1020 and 1027 (Mayapan); 1125 (Chichén Itzá); 1230 (Xelha)

Category: Fragment (Freshwater mollusca)

Total: 11

Catalog numbers: 1028-05-01 to 06, 1111-05-01, 1112-05-06,
1200-05-09, 1209-05-01 and 1209-05-02

Description: Species were not identified

Function: Undetermined, possibly subsistence or used for jewelry. Damp or wet context suggests this is the natural habitat for this species. Activity area, lakeside Coba, specimens might have been harvested as food.

Water feature context: Aguada (6), Canal (2), Well (2)

Other context: Activity area (1)

Lot distribution: 1028 (Uxmal), 1111 and 1112 (Dzibilchaltún);
1209 (Edzná); 1200 (Coba)

Category: Fragment (*Gastropoda* and *Pelecypoda*)

Total: 26

Catalog numbers: 1150-05-01, 1203-05-05 to 07, 1203-05-11 to 16, 1233-05-01, 1230-05-01 and 02, 1230-05-04, 1230-05-06 to 10, 1230-05-13 to 19

Description: Species include *Fasciolaria tulipa* (1), *Lucina pectinata* (8), *Lucina pensylvanica* (1), *Strombus gigas* (14), *Nephronaia sp* (2)

Function: Undetermined, possible fill. Some fragments exhibit cut marks that might have resulted from a tool used to fracture the specimen.

Water feature context: *Chultun* (1)

Other context: Structure (24), Mound (1)

Lot distribution: 1150 (Chichén Itzá); 1203 (Isla Cerritos); 1230 (Xelha); 1233 (Punta Lagartos)

Category: Whole specimen (*Gastropoda* and *Pelecypoda*)

Total: 8

Catalog numbers: 1203-05-08 to 10, 1229-05-01, 1230-05-03, 1230-05-05, 1230-05-12

Description: Species include *Fasciolaria tulipa* (2), *Lucina massula* (1), *Lucina pectinata* (1), *Siphonaria alternata* (1), *Strombus costatus* (1), *Lima caribal* (2)

Function: Undetermined

Water feature context: *Cenote* (1)

Other context: Structure (7)

Lot distribution: 1203 (Isla Cerritos); 1229 and 1230 (Xelha)

APPENDIX D

ABBREVIATIONS

AGU:	Aguada
AKA:	Akalchen
AKT:	Aktun
BAJ:	Bajo
BUK:	Bukte
CAN:	Canal
CAV:	Cave
CEN:	Cenote
CHU:	Chultun
EST:	Sea estavella
HAL:	Haltun
LAK:	Lake
PET:	Peten
REJ:	Rejollada
RIV:	River
SAR:	Sarteneja
SAV:	Savanna
SPR:	Spring
WEL:	Well

VITA

Terance L. Winemiller was born in York, Pennsylvania. Since graduating from Central High School, he lived in Florida, Georgia, Louisiana and now Alabama where he is an Assistant Professor at Auburn University Montgomery. In 1993, Terance graduated with honors from Rollins College, in Winter Park Florida, with a combined major in anthropology and sociology. Completion of several field schools in Mexico and Guatemala sparked his intense interest in ancient Maya civilization. While working toward his M.A. at Louisiana State University, Terance mapped portions of the site of Chichén Itzá for the Chichén Itzá Archaeological Project. After Chichén Itzá, he returned to Mexico to complete subsequent fieldwork at several Maya sites.

In 1997 Terance received his M.A. in anthropology from the Louisiana State University and began his doctoral studies in the Department of Geography and Anthropology. Terance has collaborated on several publications and his work with geographic information systems and archaeology was featured in several trade journals. His current research is an ongoing regional settlement pattern study that employs computer aided mapping, GIS, remote sensing, and global positioning systems to investigate ancient cultural systems and the role adaptive strategies played in settlement of the Maya Lowlands.